Manuscript and Technical Report Series

Project Report No. 83-01

Nova Scotia Department of Fisheries

Commercial Soft-shell Clam (*Mya arenaria*) Resource on the North Shore of the Minas Basin, 1982
-Revised-

by

Nancy B. Witherspoon

Estuarine & Inland Fisheries
Nova Scotia Department of Fisheries
April 1984

Table of Contents

	Page
List of Tables	iv
List of Figures	vi
List of Appendices	viii
Acknowledgements	ix
Abstract	x
1. Introduction	1
1.1 Economic importance of the clam fishery	1
1.2 Historical background of the Minas Basin clam fishery	1
1.3 1982 statistics	7
1.4 Reasons for the survey	7
2. Methods	7
2.1 Field procedures	7
2.2 Treatment of samples	14
2.2.1 Map Work	14
2.2.2 Numerical tabulation	15
2.2.2.1 Stock assessment	15
2.2.2.2 Determination of growth rates	17
3. Results	18
3.1 Physical setting	18
3.1.1 Bass River flats	22
3.1.1.1 Little Bass River	22
3.1.1.2 Sadies	22
3.1.2 Economy flats	24
3.1.2.1 The Tower	24
3.1.2.2 Carrs Brook	25

Table of Contents (cont'd)

Page

3.1.3 Five Islands flats..... 26

3.1.3.1 Harrington Beach..... 26

3.1.3.2 Moose Island..... 27

3.1.4 Advocate Harbour..... 27

3.1.5 Remaining non-surveyed flats..... 28

3.2 The fishery..... 28

3.3 Stock assessment..... 29

3.4 Distribution..... 37

3.5 Density..... 41

3.6 Growth..... 42

3.7 Reproduction..... 46

3.8 Catch and effort data..... 47

3.9 Landing statistics..... 49

4. Discussion..... 50

4.1 Management recommendations..... 51

5. Summary..... 53

References..... 54

Appendices..... 56

List of Tables

Table		Page
1	Number of soft-shell clams per bushel at selected sizes (from MacPhail & Medcof, 1955).....	16
2	Statistical parameters of the log-log regression of shell width (mm) on shell length (mm) for soft-shell clams in the Minas Basin, 1982.....	16
3	Parameters for von Bertalanffy growth equations for soft-shell clams from the Minas Basin (1982).....	19
4	95% confidence limits and standard error of estimates of parameters for von Bertalanffy growth equations from Table 3.....	19
5	Acreage surveyed, number of areas, number of stations, and number of clams measured for the three locations along the north shore of the Minas Basin.....	30
6	Average number/ft^2 (.09 m^2) and percentage size frequency distribution of clams sampled on the north shore of the Minas Basin for all locations combined.....	30
7	Summary of number/ft^2 (.09 m^2) and percentage size frequency distribution for the three locations and all locations combined along the north shore of the Minas Basin.....	31
8	Estimated bushels/acre of prerecruits and markets surveyed for individual locations and all locations combined on the north shore of the Minas Basin.....	36
9	Estimated production (bushels) of soft-shell clams in three locations surveyed along the north shore of the Minas Basin of the Bay of Fundy.....	36
10	Estimated acreage and bushel production ($\geq$1 3/4") of commercial clam producing locations not surveyed along the north shore of the Minas Basin of the Bay of Fundy in 1982.....	36

List of Tables (cont'd)

Table		Page
11	Estimated total acreage and potential bushel production (≥1 3/4") of soft-shell clams of both surveyed and non-surveyed areas along the north shore of the Minas Basin, Bay of Fundy, 1982	38
12	Landings (metric tons shell weight) and value (dollars) of soft-shell clams in statistical District 43, on the Five Islands-Economy shore of the Minas Basin, Bay of Fundy, from 1943-1982	38
13	Monthly commercial catch per unit effort (C.P.U.E.) for clam diggers interviewed on the north shore of the Minas Basin in 1982	48
14	Catch per unit effort (C.P.U.E.) for commercial diggers in two areas along the north shore of the Minas Basin, 1982	48
15	Soft-shell clam landings (metric tons shell weight) and value (dollars) for District 43 as compared to the totals for Nova Scotia 1980-82	48

List of Figures

Figure		Page
1	Landings of soft-shell clams on the north shore of the Minas Basin (District 43) and percentage relative to the total for Nova Scotia, 1961-1981 (from Fisheries and Oceans Statistics)	2
2	Landings and bushel values of the soft-shell clam from 1943-1982 for the north shore of the Minas Basin (from Fisheries and Oceans Statistics)	4
3	Label for canned clam product from Five Islands factory during the 1940's	4
4	Location of soft-shell clam flats on the north shore of the Minas Basin	8
5	Locations and configurations of the surveyed Bass River clam flats and positions of aging sample sites, 1982	9
6	Locations and configurations of the surveyed Economy clam flats and positions of aging sample sites, 1982	10
7	Locations and configurations of the surveyed Five Islands clam flat and positions of aging sample sites, 1982	11
8	Advocate Harbour clam flats and position of aging sample site, 1982	13
9	Locations of clam surveys conducted by the Nova Scotia Department of Fisheries	20
10	Size frequency distribution of the surveyed soft-shell clam population along the north shore of the Minas Basin, 1982	31
11	Size frequency distributions for all clams measured on (a) Bass River, (b) Economy, and (c) Five Islands flats	34
12	Size frequency distributions of clams, from inshore to offshore (areas A to D), for the Carrs Brook flat	40

List of Figures (cont'd)

Figure		Page
13	Length at age curves for slow (Site 12) medium-stunted (Site 1), and fast (Site 7) growing soft-shell clams on the north shore of the Minas Basin, 1982.....	44

List of Appendices

Appendix		Page
1	Form used for interviewing commercial and recreational clam fishermen	56
2	Length at age for soft-shell clams collected along the north shore of the Minas Basin, 1982	58
3	Details of acreage and sampling stations, frequency distributions, number/ft^2 by size class, and bushels/acre production figures for all clam-producing areas along the north shore of the Minas Basin, 1982	63

Acknowledgements

I would like to acknowledge the support of the following field staff: Valerie Billard, Clayton Eagles Jr., Jim Graham, Michelle Higgins, and Shauna Prest. Map work was completed by Valerie Billard, Clayton Eagles Jr., Jim Graham, and Shauna Prest. Valerie Billard, Marilyn Connor, Clayton Eagles Jr., Michelle Higgins, and Shauna Prest carried out data summary and analyses. Figures were drawn by Marilyn Connor.

Many commercial clam diggers are thanked for their assistance as well as clam buyers Oswald Cormier, Adrien LeBlanc, and Coreen Goguen. Local residents volunteered their knowledge of the history of the commercial fishery.

Federal protection and inspection officers Ruthven Stewart, Vernon Nuttall, Paul MacDonald, and Bernard Gower kindly offered their support to the project. Cecil Rankin, fisheries representative for the Nova Scotia Department of Fisheries, was helpful with information on the present status of the fishery. I am grateful for data contributed by the Statistics Division of Fisheries and Oceans Canada.

Marilyn Connor and Lincoln MacLeod edited the manuscript. Carol Cooper and Nina Pepper typed the report.

Abstract

A soft-shell clam survey was conducted along the north shore of the Minas Basin during the summer of 1982. Acreages, densities, frequency distributions of all size classes, and abundances of market size clams (≥1 3/4" or 42-48 mm size class) were calculated. Shell samples were collected for aging purposes. Information on the past history and present status of the fishery was gathered.

Of the estimated 1,116 acres available for commercial clam digging, 354 were surveyed. Densities of the prerecruit 1 1/2" size class (36-41 mm) were high, with relatively small numbers of <3/4" size class (0-16 mm) and ≥2" size class (≥49-54 mm). Growth rates and asymptotic lengths were low compared to other areas in the Maritimes and along the Atlantic coast of the United States. Occurrences of stunting were common. Abundances of commercial size clams were moderate, and exploitation rates were not extremely high. At the time of the survey, an estimated 67,114 bushels of market size clams, worth 1.3 million dollars, were available for harvest.

Concerns for the long term viability of this valuable and fragile resource are expressed. Management recommendations are presented.

1. Introduction

1.1 Economic importance of the clam fishery

In 1981, 1.5 million dollars worth of soft-shell clams were landed in Nova Scotia by commercial fishermen.[1] This amount exceeded the landed values of several higher profile fisheries, namely squid, gaspereau, salmon, mackerel, and queen crab. In addition, the unknown monetary worth of private clam sales and recreational digging is a bonus to the provincial economy. Nevertheless, the value of the clam industry of the province of Nova Scotia is largely underrated.

Clam landings in the Minas Basin have increased since the early 1970's (Figure 1). Now they represent approximately 30% of the total Nova Scotia clam fishery by weight. The value for the Minas Basin in 1981 was approximated at 0.5 million dollars, greater than the provincial landed values of squid, gaspereau, and salmon.

1.2 Historical background of the Minas Basin clam fishery

The clam industry in the Minas Basin began with the purchase of an old ship block factory by Willard and John Coffil around 1905 (The Women's Institute, 1969). Located along the North River in the community of Five Islands, it became primarily important for canning clams, although some clams were sold fresh in the local area. The factory employed less than six diggers in the beginning. Workers preferred the forest, fishing, farming, and tourist industries, in which jobs were abundant and better pay was provided.

---

[1] Using data provided by the Statistics Division of Fisheries and Oceans Canada, soft-shell clam statistics cited in this report were calculated by adding statistics for "unspecified clams" to those for "soft-shell clams". The reason for this is, according to Fisheries and Oceans Canada, 90-100% of unspecified clam landings are actually soft-shell clams.

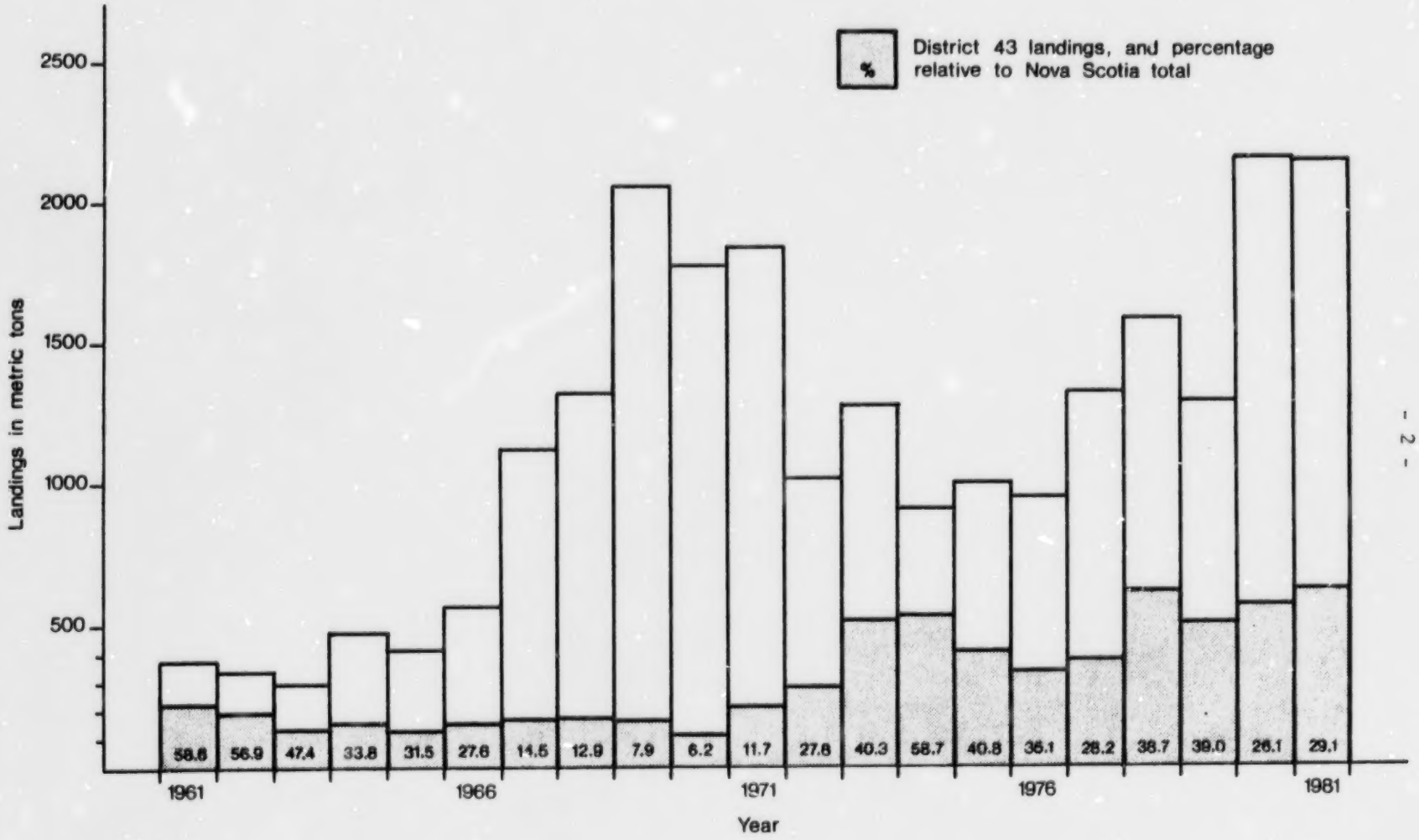

Figure 1. Landings of soft-shell clams on the north shore of the Minas Basin (District 43) and percentage relative to the total for Nova Scotia, 1961-1981 (from Fisheries and Oceans Statistics).

By 1910, the clam factory had burnt down, and was rebuilt nearby on Broderick's Beach. Shortly afterward, Dr. Archibald Davidson bought and named it the Evangeline Clam Factory. His nephews, Perley and Allan Davidson, ran the factory for him; later Dr. Davidson sold the Factory to the nephews. The business changed hands once more in 1915. The new owner, Isaac Fulmer, bought clams for $1.00 a barrel (2 1/2 - 3 bushels). A day's catch was hauled in from the flats by dory at high tide, cleaned, cooked, and canned. The majority of the product was shipped to markets in the United States. Except for a temporary exchange of ownership with a Mr. Pridham around 1918, the clam business under Fulmer remained relatively unchanged up until the 1940's.

By 1941, a commercial fishery had started in Parrsboro Harbour. In 1942, a man from New Brunswick, Aurele LeBlanc, purchased and expanded the canning plant. Between 1938 and 1943, the price for clams rose from 33 to 85 cents per bushel. The number of diggers climbed to one hundred, and the landings increased dramatically (Figure 2). The overnight boom in the clam industry was sparked by greater demand for the product and restricted fishing in the Minas Basin due to airforce bombing and gunning practices (Medcof, 1949).

LeBlanc's factory, employing approximately fifty people, produced canned clams under the "Bay of Fundy Brand" label (Figure 3). Both diggers and factory workers were being brought in from New Brunswick, but later, more people from the area participated in the industry.

The only fishery regulation at that time was a 2 1/4" (57 mm) size limit applying to all commercial clam fisheries in Nova Scotia. The provincial government was concerned about the lack of regulation size clams on the flats along the Five Islands Shore. They asked federal government officials to investigate this problem. Scientists

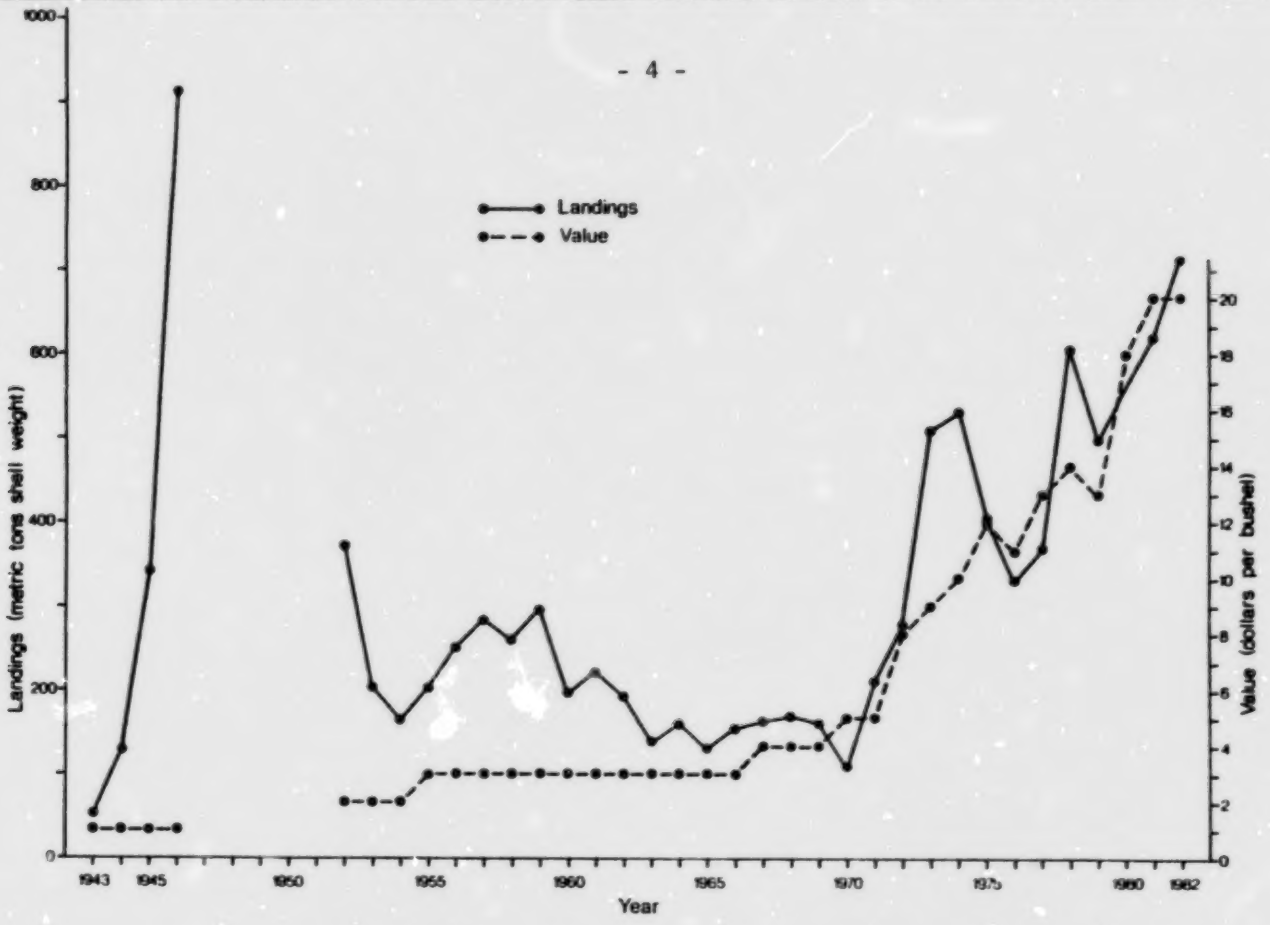

Figure 2. Landings and bushel values of the soft-shell clam from 1943-1982 for the north shore of the Minas Basin (from Fisheries and Oceans Statistics).

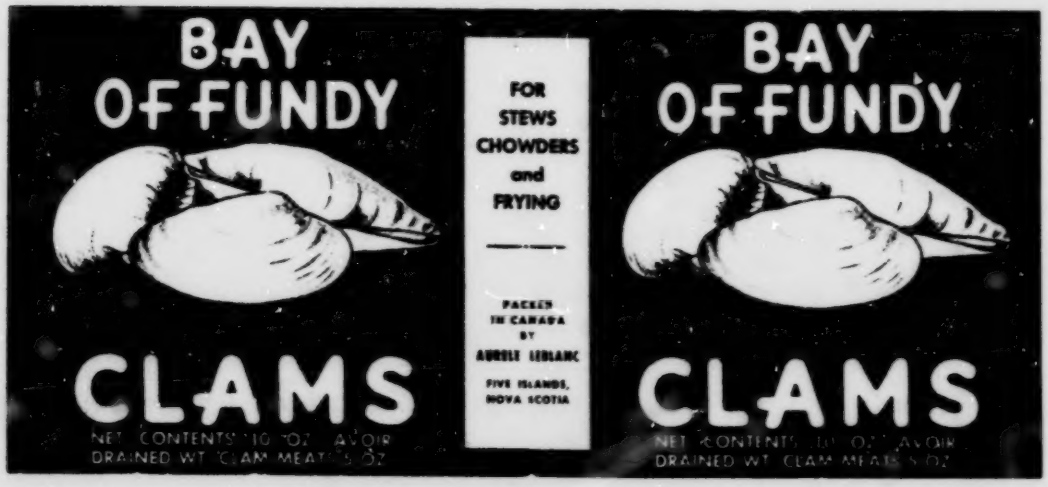

Figure 3. Label for canned clam product from Five Islands factory during the 1940's.

from St. Andrews Research Station found large portions of stunted, slow growing, and old clams less than legal size on the commercially dug flats (ibid.). They concluded that many clams would die before reaching the size limit, and recommended that it either be reduced to 1 3/4" (45 mm) or be abolished entirely. On May 12, 1944, the size limit was revoked for the area. In practice, very few clams were harvested below 2" (51 mm) because larger clams were more economical to shell (i.e. they provided more meat weight per unit of effort).

Clam digging expanded to the Economy area, and from 1946 - 1947, a clam factory operated at Carrs Brook. It was during this period that the highest landings up until that time were recorded (Figure 2). Catch per unit effort (CPUE) statistics (bushels per person per tide) were high. An average catch was 8 bushels for a five hour tide. Occasionally, 14 bushels were taken in a productive area during a long tide.

Landings declined from 1948 to 1970. The number of fishermen dropped from an average of 100 clam diggers per year during the 1940's to figures ranging between 20 and 70 per year for the following two decades. Prices continued to remain relatively stable: the two dollar value of a bushel of clams in 1952 rose to three dollars in 1955, staying at that amount until 1966. Lower prices coupled with the CPUE being reduced to 3-4 bushels per tide were indicative of a less prosperous fishery. Fishermen were forced to venture further afield to places such as Advocate Harbour in order to make a living.

On December 24, 1960, LeBlanc's factory burned down (The Women's Institute, 1969). It was rebuilt in 1961 closer to the main highway. A Mr. Murcheson purchased the factory in 1967 and resold it a year later to D.A. Casey. It changed hands a few more times, Casey selling to a Mr. Massey who in turn sold it to Peter Marcus. In 1969 or 1970, the factory was again destroyed by fire.

The 1960's saw some changes in the industry which improved the economic climate in subsequent years. The law prohibiting the shipment of clams in the shell outside the province was abolished in 1967. This annulment allowed live clams to be exported to the province of Quebec for Expo '67. By the end of the decade, the transition from a canned product to fresh, shucked clams had occurred in response to the American deep-fried trade. In addition, reduced effort in previous years had given clam stock densities time to recover.

Around 1970, Coreen Goguen and Adrien LeBlanc started buying clams chiefly for sale to New Brunswick. A year later, Oswald Cormier built and opened a new clam factory on the road to Sand Point, closer to central Five Islands. Prices increased rapidly as markets grew, and landings and number of diggers again were on the rise. CPUE statistics averaging 4-5 bushels per tide reflected somewhat improved abundances.

Licensing of commercial clam diggers was required by the federal government from 1978. Parrsboro Harbour and the mouths of East and Harrington Rivers in Five Islands were closed to commercial fishing by 1979 because of faecal bacterial pollution.

Market-size clams (≥1 3/4", ≥42-48 mm size class)[2] have been shucked in Five Islands for both local, Maritime, and U.S. consumption since the 1970's. The remainder is shipped to New Brunswick for processing or further distribution. Larger proportions of small clams (1 1/2" - 1 3/4", 36-48 mm size classes), called steamers, have been dug for live sale to U.S. markets from 1980 to the present.

---

[2]The clam industry basically uses the Imperial system to measure clams. For this study, size classes were chosen to place clams in metric length groupings represented by a single Imperial measure. For example, the metric range of the 1 3/4" size class is 42 to 48 mm (see Tables for breakdown). When not referring to size classes, the actual metric equivalent is used: e.g., 1 3/4" = 45 mm. Measurements other than clam lengths are metric.

1.3 1982 statistics

A peak of 710 MT of clams, worth over 0.5 million dollars, has been reported for the Minas Basin, District 43, for 1982. One hundred and ten full-time commercial diggers, plus numerous part-timers and students, were engaged in the fishery. There were three plants in the area with a hired staff of twenty-seven people to process the harvest. CPUE's averaged 2 1/2 - 3 bushels per person for a four hour tide. Reduced abundances have again induced fishermen in recent years to travel west to Advocate Harbour to augment their catches.

1.4 Reasons for the survey

Historically, the Minas Basin clam fishery has fluctuated in prosperity relative to clam abundances, market demand, increased effort, and subsequently, landings. The size of the market clam has mainly been above 1 3/4" (42-48 mm size class) for economic reasons. However, the absence of a size limit and the relaxation of export regulations have made possible the recent exploitation of smaller clams.

Besides management problems in the fishery, there are threatening environmental issues. A proposed tidal power barrage from Economy Point to Cape Tenny (B in Figure 4) could have an impact on the clam resource in the region. Furthermore, continued problems with bacterial pollution are likely, unless sanitary practices in the area are improved.

Concern for future viability of the clam fishery on the north shore of the Minas Basin prompted this investigation by the Nova Scotia Department of Fisheries during the summer of 1982.

2. Methods

2.1 Field Procedures

Pre-survey work involved the identification of 17 clam flats of

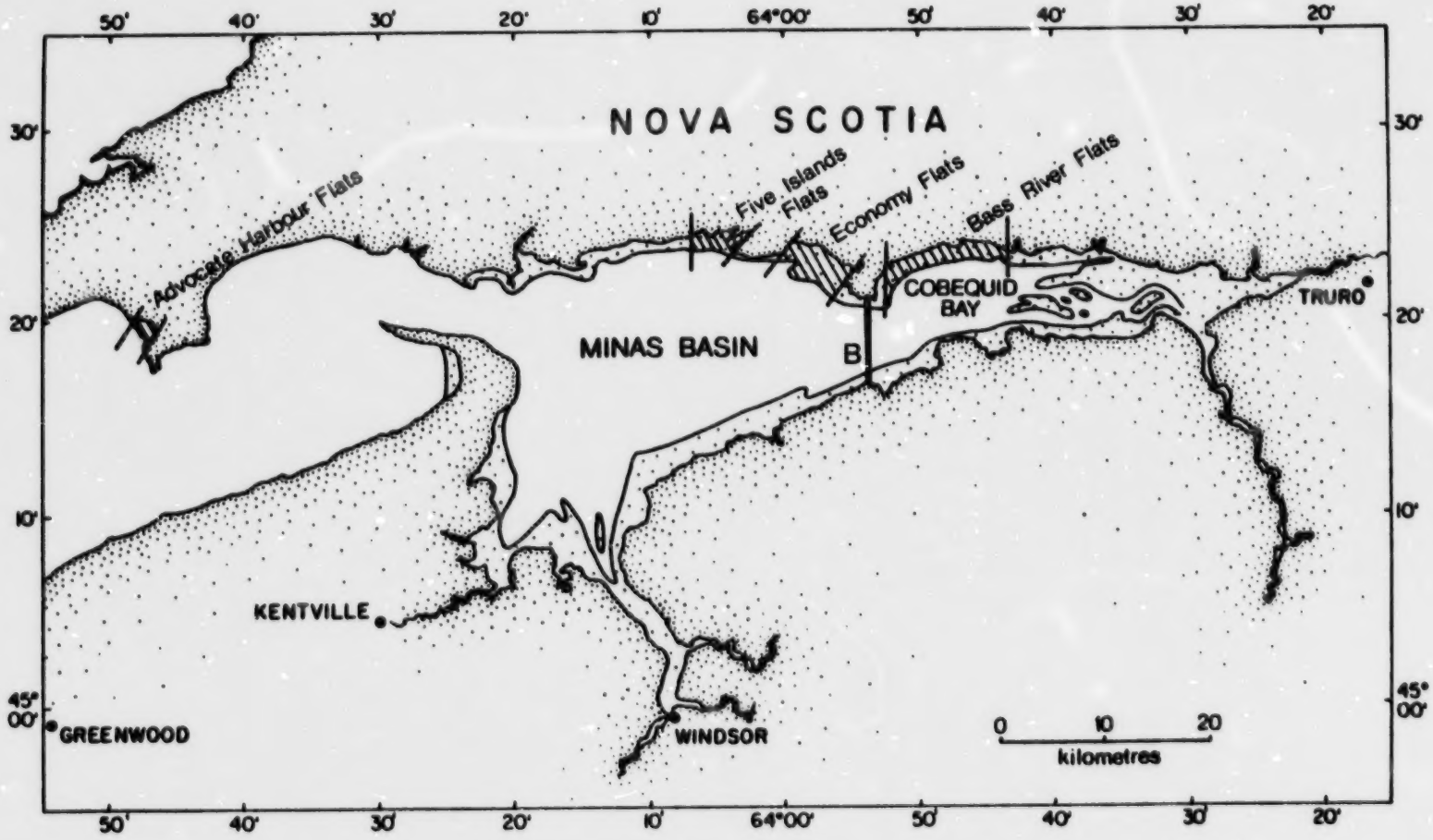

Figure 4. Location of soft-shell clam flats on the north shore of the Minas Basin (modified from: Geomorphology and sedimentology of the Bay of Fundy, Trip 23 of the Geological Association of Canada and the Mineralogical Association of Canada, May 1980, authors C.L. Amos et al.). The proposed position of the tidal power barrage is indicated by the letter "B".

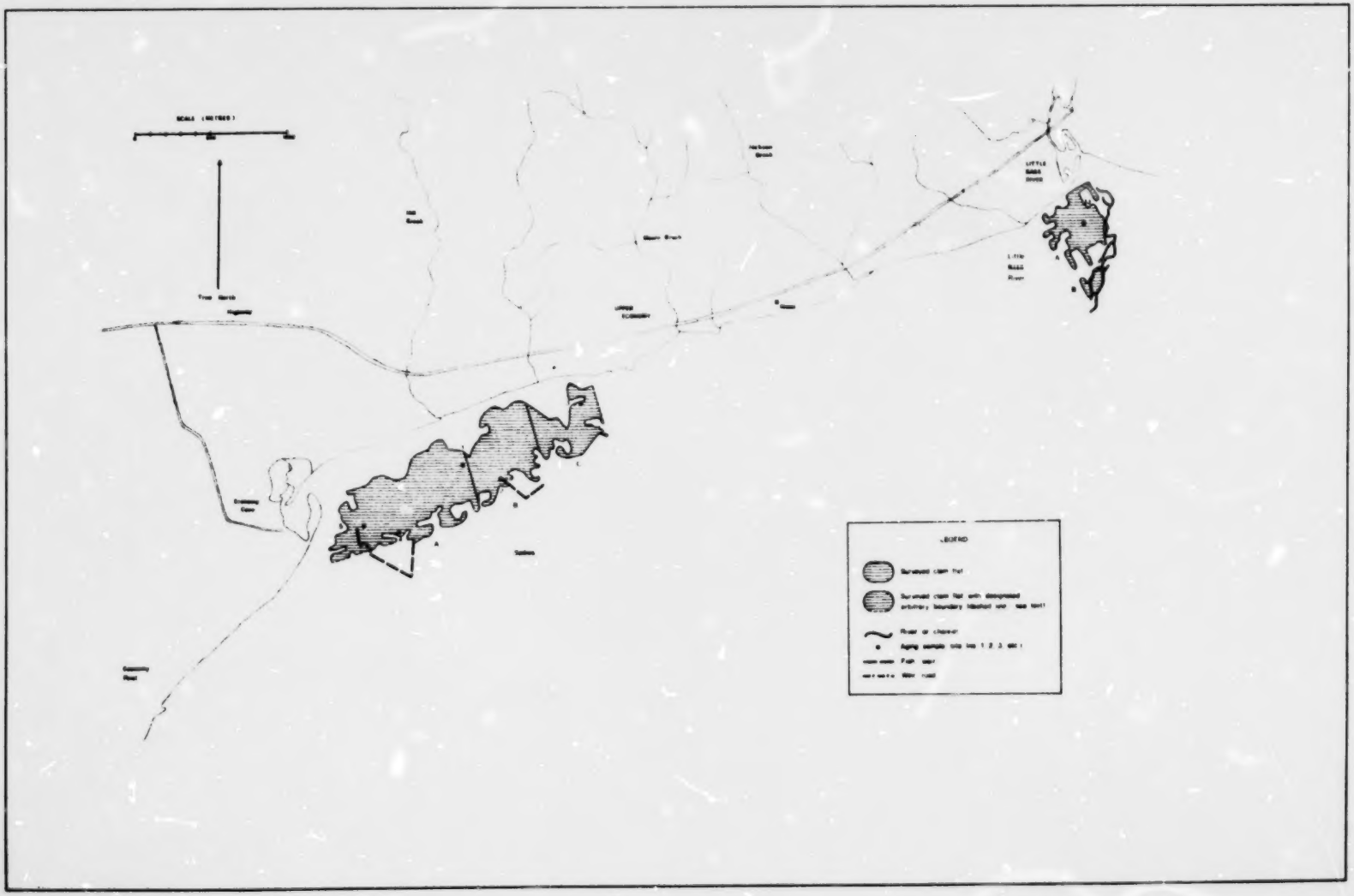

Figure 5. Locations and configurations of the surveyed Bass River clam flats and positions of aging sample sites, 1982.

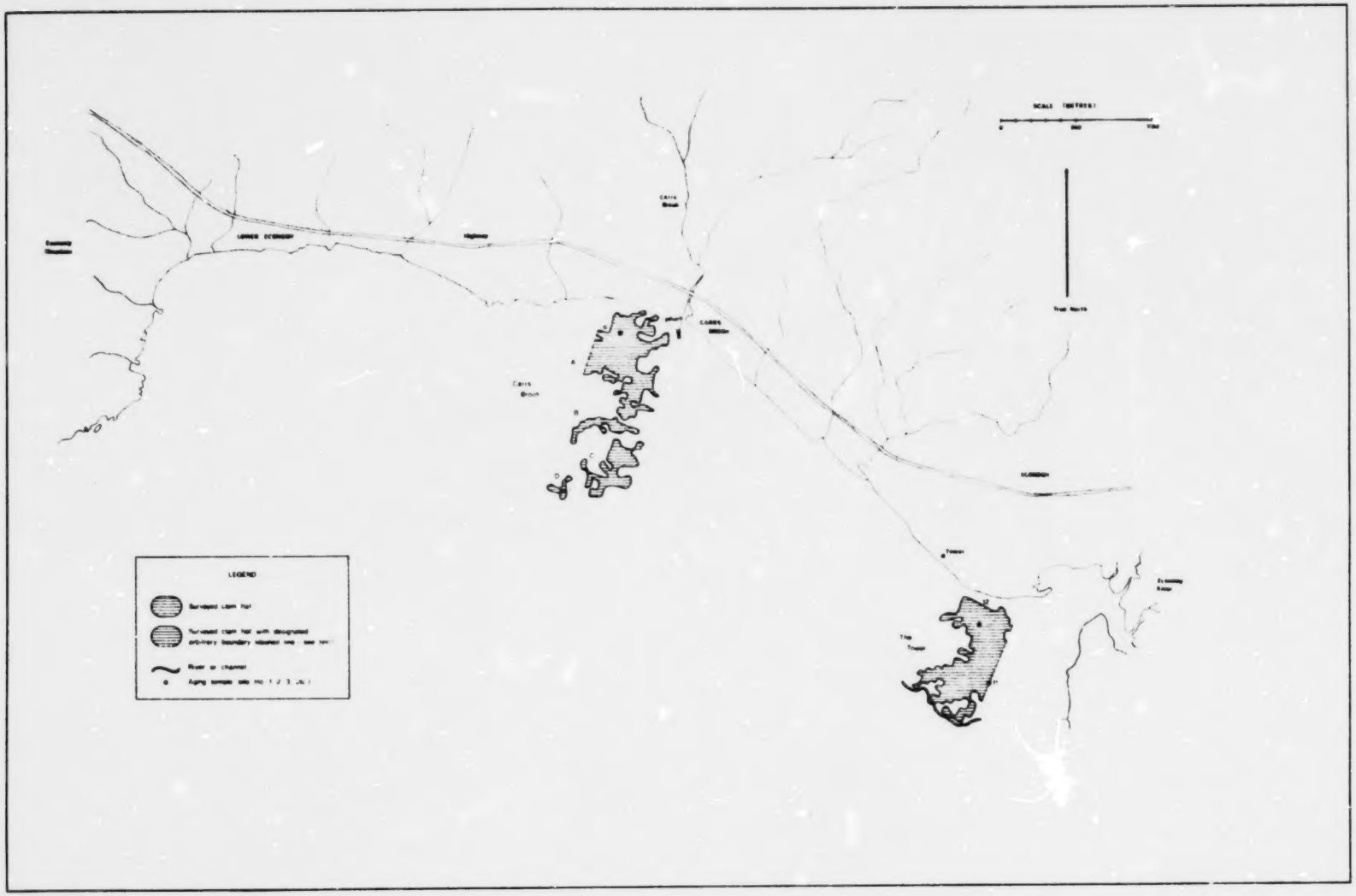

Figure 6. Locations and configurations of the surveyed Economy clam flats and positions of aging sample sites, 1982.

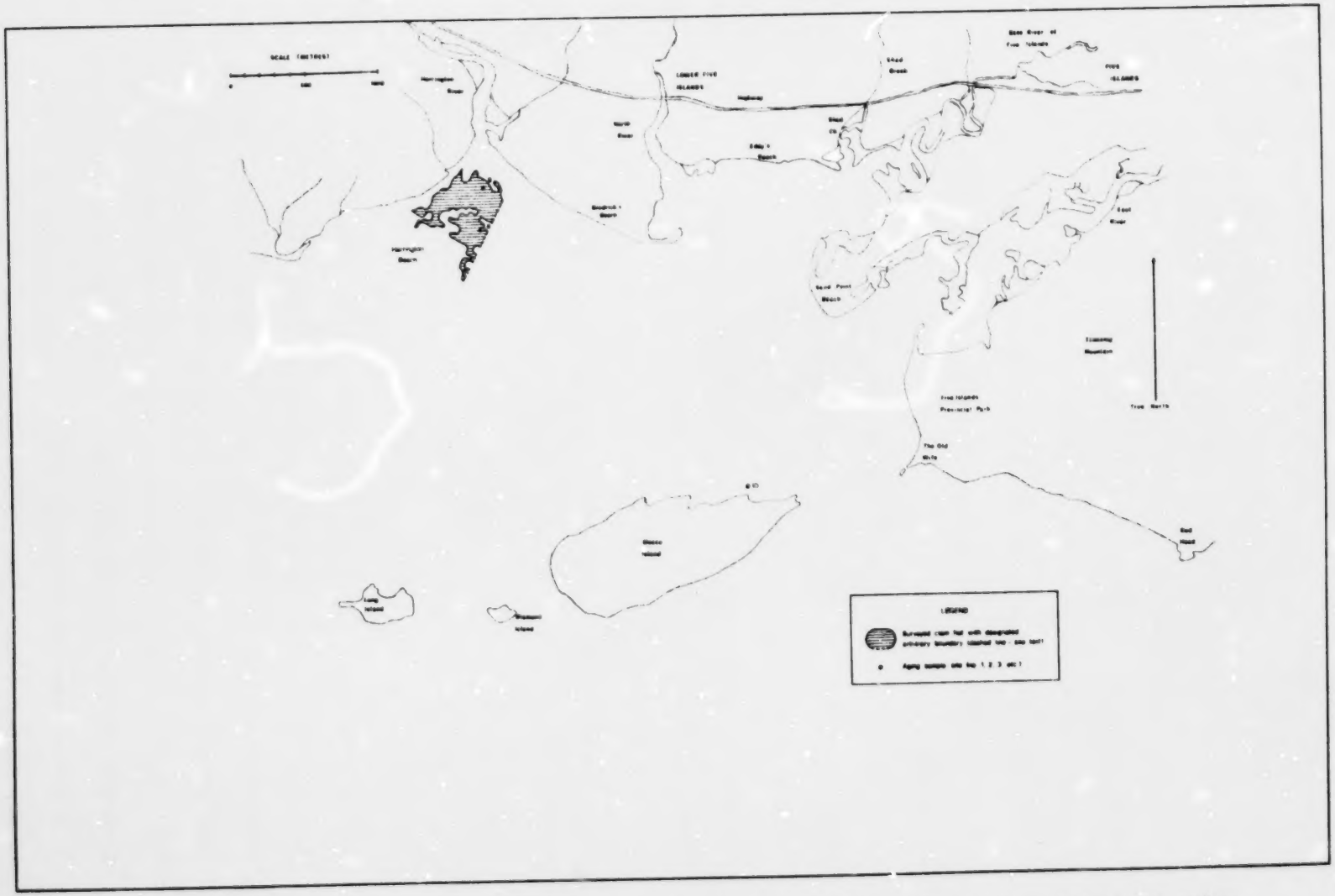

Figure 7. Locations and configurations of the surveyed Five Islands clam flat and positions of aging sample sites, 1982.

commercial importance. Fishermen and processors provided information on past and present commercial productivity of these flats, from which a priority list was constructed. The five flats considered most important, and chosen for detailed survey work, were: Sadies, Carrs Brook, Harrington Beach, The Tower, and Little Bass River (Figures 5, 6, and 7). Fortunately, these flats are distributed throughout the major commercially exploited area along the north shore of the Minas Basin; they are also distributed on either side of Economy Point, the northern attachment site of the proposed tidal power barrage.

The remaining flats were not surveyed due to time constraints, but were visited to determine approximate acreages and clam densities. From east to west, these included: Five Houses, Saint's Rest, The Miller Place, Soleytown, Lower Economy, The Old Wife, Sand Point, Eddy's Beach, Broderick's Beach, Moose Island, and Blue Sac Beach (Figures 5, 6, and 7); and Lubber Hole and Advocate Flat (Figure 8). All 17 flats were arbitrarily grouped under four locations (Figure 4): Bass River flats (east of Economy Point), Economy flats (east of Economy Mountain, west of Economy Point), Five Islands flats (west of Economy Mountain), and Advocate Harbour flats.

The actual field work commenced on May 25th and ended September 20th. Transect line and quadrat techniques, similar to those used in clam survey work conducted on the Eastern Shore in 1981 (Witherspoon, 1982), were employed, with some modifications. Access to most clam flats was made on foot, with the exception of Moose Island. Aluminum stakes were used to mark quadrat locations. The majority of samples were sorted by hand; consequently, clams less than 20 mm are likely underestimated. Transect lines were consistently 30 m apart parallel to the shore and 50 m apart perpendicular to the shore. In all areas except Little Bass River, surveying could have continued beyond the boundaries indicated (see arbitrary boundaries, Figures 5, 6, and 7). However, due to a lack of

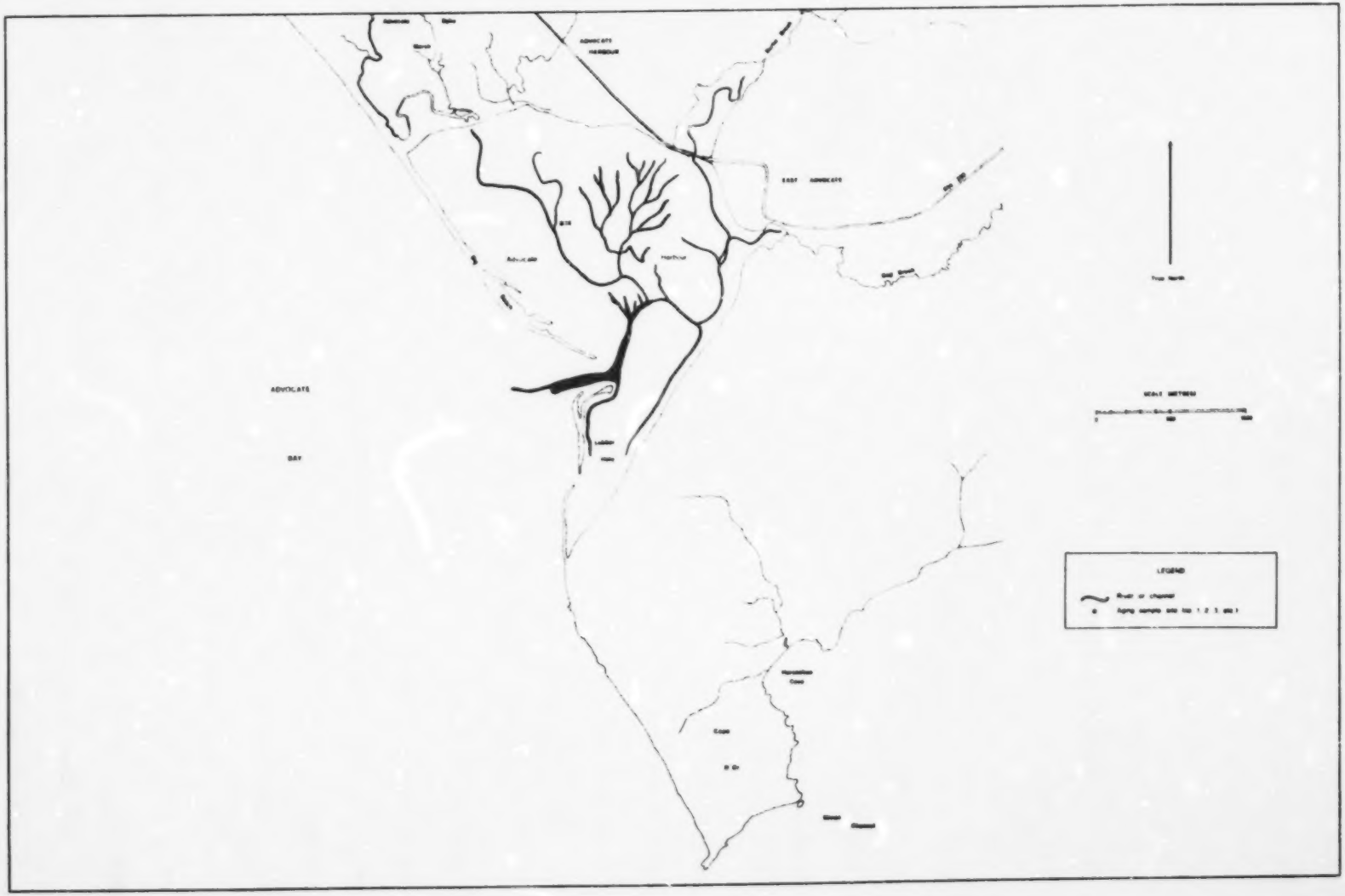

Figure 8. Advocate Harbour clam flats and position of aging sample site, 1982.

time, the work was discontinued beyond areas considered most commercially important.

Those areas that were not surveyed by the transect line and quadrat method (referred to hereafter as unsurveyed areas) were assessed using a less detailed method. With the aid of map and compass, distance was paced on foot from the beginning of the clams in the upper part of the intertidal zone to where they ended in the lower part. At 90 m intervals along each pacing line, visual approximations of densities and sizes of clams were made from square-foot-hole counts and digs. In each area, pacing lines were spaced 90-150 m apart along the shoreline and ended where absence of commercial digging or significant densities of clam holes was evident.

Fourteen sites on a number of commercial flats, at different tidal heights and in varied substrate types, were chosen for collection of aging samples (Figures 5, 6, 7, and 8). Samples were immediately processed and shells were saved for future aging.

Observations on meat condition were made from June through September.

Clam digger counts and random interviews were conducted when time permitted. Commercial fishermen were questioned about their catch, effort, and other information related to the commercial fishery (Appendix 1). Recreational fishermen also responded to questions concerning the relative importance of clam digging to their holiday plans.

Clam landing data was obtained from Fisheries and Oceans, Statistics Division. Historical information on the fishery was collected through interviews with processors, diggers, fisheries officers, and residents of the Five Islands-Economy area.

2.2 Treatment of Samples

2.2.1 Map Work

Map and compass methods were identical to those used in the 1981

study (Witherspoon, 1982). Great distances between quadrat locations and sighting points, as well as rapidly eroding shorelines, caused some difficulties in reconstruction of surveyed areas during map drawing.

2.2.2 Numerical Tabulation

2.2.2.1 Stock Assessment

Clams were grouped into size classes, as in the 1981 study. Inspection of size frequency distributions indicated that clams were partially exploited from 1 3/4" (42-48 mm size class) and above. Two types of groupings of prerecruits and markets were used for data analysis:

Type I	Type II
Juveniles $\leq$ 1 1/4" ($\leq$35 mm)	Juveniles $\leq$ 1 1/4" ($\leq$35 mm)
Prerecruits 1 1/2 - 1 3/4" (36-48 mm)	Prerecruits 1 1/2" (36-41 mm)
Markets $\geq$2" ($\geq$49 mm)	Markets $\geq$1 3/4" ($\geq$42 mm)

The Type I grouping was included so that comparisons could be made with abundances of clams in other areas of the Maritimes where 2" (51 mm) is the minimum legal harvest size.

Summaries of acreages, number of stations, and clams measured were prepared by location, flat, and areas within flats. Tables of size classes, densities in number of clams per ft^2 (0.09 m^2), bushels per acre, and total bushel production were completed. Bushel calculations were done for prerecruits and markets, Types I and II. Conversions from number of clams per size class to bushels were made using Table I.

Table 1. Number of soft-shell clams per bushel at selected sizes (from MacPhail & Medcof, 1955).

Size (length) mm	inches	Clams per bushel
36-41	1 1/2	2800
42-48	1 3/4	2200
49-54	2	1600
55-60	2 1/4	1180
61-67	2 1/2	920
68-73	2 3/4	700
≥74	≥3	560

Table 2. Statistical parameters of the log-log regression of shell width (mm) on shell length (mm) for soft shell clams in the Tidnish Basin, 1982.

log (shell length) = log α + β log (shell width)

Site	Location	n	α	β	95% confidence limits α		95% confidence limits β		r^2*
1	Sadies A - Midshore	187	.4905	.806	.4456	.5353	.773	.840	.961
2	Sadies B - Offshore	195	.3455	.926	.2814	.3453	.903	.950	.984
3	Sadies C - Inshore	201	.3266	.939	.2792	.3741	.905	.974	.967
4	Sadies A - Offshore	210	.3776	.899	.3369	.4184	.870	.929	.972
5	Sadies A - Inshore	204	.3417	.923	.2731	.3503	.894	.952	.975
6	Carrs Brook - Inshore	192	.3440	.927	.3011	.3868	.896	.957	.974
7	Carrs Brook - Offshore	209	.2670	.972	.2399	.2942	.952	.992	.989
8	Harrington Beach - Offshore	219	.2701	.965	.2378	.3030	.941	.989	.983
9	Harrington Beach - Inshore	202	.2975	.939	.2735	.3215	.922	.957	.991
10	Moose Island - Midshore	166	.3051	.919	.2551	.3511	.912	.985	.971
11	The Tower - Offshore	224	.2656	.969	.2281	.3030	.942	.997	.977
12	The Tower - Inshore	193	.3455	.919	.2804	.4067	.873	.964	.944
13	Little Bass River - Midshore	276	.2571	.973	.2091	.3052	.938	1.009	.956
14	Advocate Harbour - Offshore	229	.2821	.956	.2453	.3188	.930	.982	.979

*Correlation coefficient

Graphical representations of size frequency distributions (number per ft^2 or 0.09 m^2) were produced for each location where surveys were conducted, for all locations combined, and for illustrating any differences from inshore to offshore intertidal areas.

With the information gathered from the unsurveyed flats, areas of commercial abundances were mapped and acreages calculated. Average densities per ft^2 (0.09 m^2) were approximated for each area from the data collected. These results were compared to densities and size distributions of clams from surveyed areas. To approximate bushel production in unsurveyed areas, bushel per acre figures of market size clams ($\geq$1 3/4", $\geq$42-48 mm size class) derived for surveyed areas were applied to unsurveyed areas which were similar in clam habitat characteristics. Tables summarizing acreages and bushels of market size clams are presented by unsurveyed areas and by locations.

Grand total acreage and bushel production of clams at least 1 3/4" (42-48 mm size class) are given for both surveyed and unsurveyed areas and locations.

CPUE statistics were calculated for commercial fishermen on a monthly basis and for two clam flats where data was sufficient. Total 1982 CPUE's were summarized for both commercial and recreational fishermen.

2.2.2.2 Determination of Growth Rates

Methods used for aging clams and analyzing the data were identical to those used in 1981 (Witherspoon, 1982). Young clams spawned in the summer months lay down their first growth ring the following winter. This ring becomes worn in older clams; it is very difficult to read and therefore is ignored. Ring 2 is recorded as age 1 and is the first ring which presents a full year's growth.

Shell widths are converted to lengths and then are run against age using the von Bertalanffy growth equation

$$L_t = L_\infty (1-e^{-k(t-t_o)}).$$

Theoretical values of growth parameters L_∞ (length at which the growth rate is 0; i.e., maximum theoretical length), k (rate of growth to L_∞), and t_o (age at which length is 0) were generated.

Statistical parameters of the allometric equation

$$\log (\text{shell length}) = \log \alpha + \beta \log (\text{shell width}),$$

used to convert clam widths to lengths, are presented in Table 2 for all fourteen aging sites. Tables 3 and 4 list the parameters of the von Bertalanffy growth equation, with confidence limits and standard errors, for each aging site. Fitted and measured lengths at age are given in Appendix 2. Plots of growth curves are used to illustrate the range of k and L_∞ values.

3. Results

3.1 Physical Setting

The main study area, containing approximately 40 km of coastline along the north shore of the Minas Basin from Bass River to Five Islands, is located 40 km west of Truro (Figure 9). Advocate Harbour, situated at the entrance to the Minas Channel, is about 65 km further west.

The former area is dominated by highly erodable sandstone cliffs, broken at intervals with rivers having salt marshes at their mouths. The clam flats vary in width (measured from shore to sea) from 500-1,000 metres. River and tidal drainage channels dissect the flats in a number of places. The substrate type varies markedly, and can range from soft, oozy mud to sand and gravel. In general, however, sediments are finer near shore and get progressively coarser seaward. Substrate depth is also highly variable: underlying hard pan clay or sandstone

Table 3. Parameters for von Bertalanffy growth equations for soft-shell clams from the Minas Basin, 1982.

Site	Location	n	L_∞	k	t_o
1	Sadies A-Midshore	870	56.477	.154	-1.127
2	Sadies B-Offshore	791	56.067	.183	-.588
3	Sadies C-Inshore	1083	62.895	.156	-.455
4	Sadies A-Offshore	870	80.892	.138	-.273
5	Sadies A-Inshore	785	56.604	.171	-.440
6	Carrs Brook-Inshore	707	86.399	.154	-.123
7	Carrs Brook-Offshore	594	74.852	.201	+.001
8	Harrington Beach-Offshore	618	77.360	.160	-.408
9	Harrington Beach-Inshore	610	60.362	.220	-.177
10	Moose Island-Midshore	458	69.058	.191	-.202
11	The Tower-Offshore	691	59.986	.210	-.321
12	The Tower-Inshore	702	99.471	.109	-.331
13	Little Bass River-Midshore	1152	89.822	.097	-.255
14	Advocate Harbour-Offshore	1025	79.592	.127	-.392

Table 4. 95% confidence limits and standard error of estimates of parameters for von Bertalanffy growth equations from Table 3.

Site	Location	95% confidence limits						standard error		
		L_∞		k		t_o		L_∞	k	t_o
1	Sadies A-Midshore	54.124	58.830	.142	.167	-1.215	-1.038	1.201	.0064	.0451
2	Sadies B-Offshore	53.683	58.451	.168	.199	-.660	-.516	1.216	.0077	.0367
3	Sadies C-Inshore	61.379	64.410	.149	.164	-.497	-.413	.773	.0036	.0215
4	Sadies A-Offshore	78.481	83.303	.132	.145	-.304	-.242	1.230	.0033	.0159
5	Sadies A-Inshore	54.390	58.817	.159	.182	-.490	-.391	1.129	.0060	.0251
6	Carrs Brook-Inshore	83.766	89.033	.146	.161	-.155	-.092	1.344	.0039	.0161
7	Carrs Brook-Offshore	72.857	76.846	.191	.211	-.033	+.035	1.018	.0052	.0173
8	Harrington Beach-Offshore	73.958	80.762	.148	.171	-.453	-.363	1.736	.0060	.0231
9	Harrington Beach-Inshore	59.357	61.368	.212	.228	-.203	-.150	.513	.0039	.0136
10	Moose Island-Midshore	66.002	72.114	.177	.205	-.245	-.159	1.559	.0073	.0217
11	The Tower-Offshore	58.818	61.154	.202	.218	-.351	-.291	.596	.0041	.0152
12	The Tower-Inshore	89.047	109.896	.093	.124	-.379	-.283	5.319	.0078	.0245
13	Little Bass River-Midshore	85.693	93.952	.091	.103	-.282	-.228	2.107	.0031	.0137
14	Advocate Harbour-Offshore	77.814	81.370	.123	.132	-.418	-.366	.907	.0024	.0132

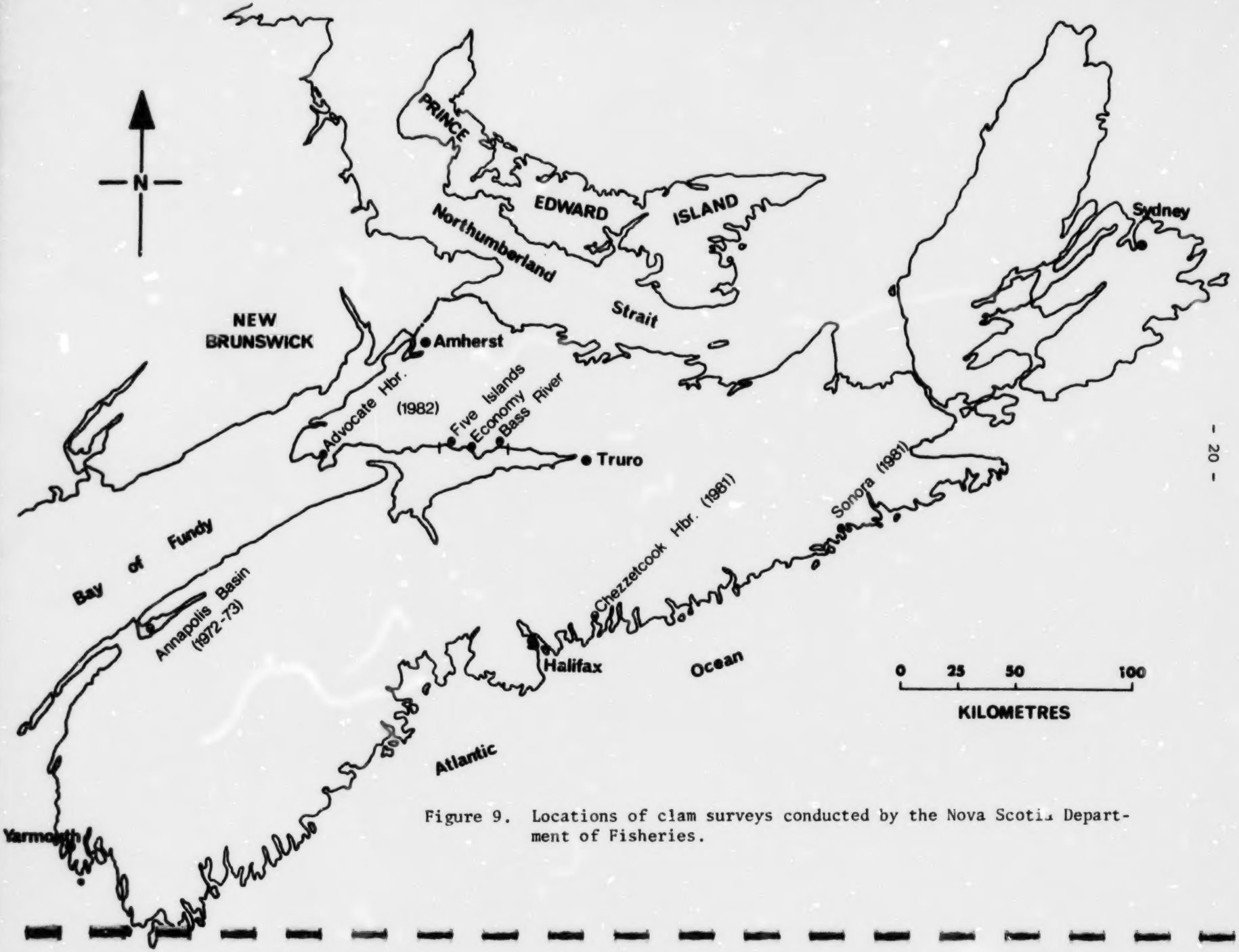

Figure 9. Locations of clam surveys conducted by the Nova Scotia Department of Fisheries.

ledges can reduce depths to less than 10 cm.

Advocate Harbour is a sheltered, sandy embayment, adjoined by marshgrass flats to the north. Brooks enter the harbour on the east and north sides (Figure 8). The embayment is characterized by large river and drainage channels and high gravel bars close to its seaward entrance. Clam flats are found between these channels, primarily in the centre of the harbour.

Generally, flats of major commercial importance are found opposite river mouths, in sheltered coves, and in the lee of headlands. Distribution of clams is usually patchy and seems to be dependent on a variety of factors, including sediment type and depth, height in the intertidal zone, and position relative to tidal and river drainage channels. Highest densities of clams are found in well drained, medium grained, moderately deep (> 10 cm) sediment types. A preference for the lower-middle to middle-upper part of the intertidal zone, and the banks of tidal and river channels, was consistently observed. Commercial digging is most intense in these locations.

The Bay of Fundy is unique because it has the world's highest tides. In the Minas Basin, this large water movement, combined with westerly fetch, storm-driven waves and winter ice conditions, result in an intertidal zone susceptible to dramatic erosional and depositional changes over very short periods of time. Yeo (1978) has aptly described this region as a high energy, low stability environment. Fast and efficient rates of carbon and nutrient transfer from one trophic level to the next produce a high density, low diversity assemblage of infaunal invertebrates. The region lays claim to some of the highest biomass production values recorded in the literature.

3.1.1 Bass River Flats

3.1.1.1 Little Bass River

The flat at Little Bass River, the most easterly area surveyed, was divided into sections A and B due to an absence of clams between the two sections (Figure 5). Although a relatively small flat (513 m wide), it is actively dug every spring.

This flat is characterized by variable sediment types ranging from soft mud along the channel of the Little Bass River, which produces no clams, to mud-sand-gravel mixtures inshore, which have moderately dense quantities of clams. Areas of heavy gravel or rippled sand in the outwash of the river offshore have no clams, while sediments to the west hold large white clams clumped together.

Only one aging site on this flat was selected (site 13, midshore). Stratified sediments of mud over sand and gravel yielded mostly medium-sized clams. The area had been dug by commercial harvesters.

3.1.1.2 Sadies

Because of its large size, Sadies was arbitrarily broken into areas A, B, and C for ease of surveying (Figure 5). Mean widths of the three areas were 433, 462, and 353 m, respectively. Approximately 120 m covered the distance from high water to the beginning of significant clam abundance.

Sediment type graded from fine grained mud-clays in the west (Sadies A), into mud-sand of the central section (Sadies B), to sand-gravel in the most easterly area (Sadies C). The river and associated salt marsh close to Sadies A seem to contribute the fine grained black muds which predominate in this area. Small brooks running through sandstone cliffs add coarse grained sands and gravels to the more easterly portions of the flat. Sandstone outcrops, which occur as ledges, and hard-

pan clay bottoms produce shallow substrates (<10 cm) in portions of Sadies C.

Clams were concentrated in medium grained mud-sands of Sadies B, and alongside intertidal waterways common in Sadies A. Large numbers of dead shells were noted among them. Observations made on these flats, common to many flats studied, were: fine soft muds or heavy gravels yielded very few clams; clams were found deeper in sand than in mud; and fish weirs, characterized by numerous channels and coarse-grained sediments, had few clams.

Juvenile clams (<3/4", 0-16 mm size class) from the previous year's spawning were apparent in relatively high numbers in surface sediments of Sadies C.

This flat has produced the greatest quantity of commercial clams in the area in the last 2 years. In 1982, approximately 18% of the catch from the north shore of the Minas Basin was taken from Sadies.

Five samples of clams from five different sites were collected for aging purposes. Site 1, located midshore and at the upper edge of commercial digging in area A, was characterized by a sand-gravel base and mud surface. Clams were found in very dense aggregations, and were thick shelled and small in size. Site 2, area B, was situated offshore in an area of commercial digging. Inhabiting predominantly sandy substrates, the clams were thin shelled and of a wide size range. Inshore, site 3, area C, was representative of shallow ledge, sand-gravel substrates. Clams were smaller and found in lower densities here than in the other two sites. Seaward from this site there was evidence of commercial digging. Positioned at the opening of the fish weir in area A, site 4 was occupied by black-shelled clams in moderately dense aggregations. The animals were generally larger and of a wide size range. The bottom was sand-gravel mixed with black mud which causes surface darkening of

shells. Site 5, area A, was chosen as a location of very dense quantities of clams. Situated adjacent to a river channel, the clams were small, squat, and of approximately equal size. There was no commercial digging nearby.

Stunted clams, particularly prominent in most samples except site 4, were observed to be thick shelled. Jagged marks between annual growth rings were assumed to be shock marks indicative of disturbances resulting from intense digging practices on this flat. The animals here had highly variable ring 2 positions as well as large differences in growth rates between rings within animals, and between animals within the same rings.

3.1.2 Economy Flats

3.1.2.1 The Tower

The Tower is situated at the mouth of the Economy River (Figure 6). For the previous four years, this flat had not been heavily dug by commercial fishermen. Recruitment of a moderately dense year class in 1982 led to intense exploitation of both this flat and a similar one across the river channel called the Miller Place (not surveyed).

The Tower was approximately 641 m wide. Inshore sediments were composed of black mud intermixed with a little sand. There were thick blue clays underneath, sometimes containing decomposing marsh grass which gave off unpleasant sulphur odours. Offshore areas had mud surfaces with higher proportions of sand below.

The greatest density of clams sampled in this 1982 survey was dug on this flat (152 per ft^2 or 0.09 m^2). Densities were high over the entire flat. Clams were patchy to the west of the area surveyed, and found in high concentrations only along tidal channels or in the lee of large boulders. To the east, there were larger proportions of gravel in the sediments and therefore lower densities of clams.

Offshore sample site 11, situated adjacent to the main river channel, was composed of a mud-sand-gravel substrate. Stunted clams of variable sizes were present in high density. Inshore site 12 contained a black mud substrate over blue clay; moderate-sized clams were black-shelled, and fewer in number than at site 11.

3.1.2.2 Carrs Brook

When compared to the other areas surveyed, this flat had the widest intertidal zone (Figure 6). Beginning at about 60 m from the high water mark, it stretched 1,154 m seawards. Sand and gravel high in the intertidal zone graded into mud-clays midshore and then sand-gravels off-shore. A small salt marsh at the mouth of Carrs Brook contributes to the organic muds found on the flat.

The whole of the Carrs Brook flat was sampled, but only areas A, B, C, and D had any commercial quantities.

Densities of clams appeared to be relatively lower here than on other flats surveyed. Noticeably fewer clams were found in the central portion of the flat (area B), which was reportedly a result of intense digging in the spring. Heaviest commercial exploitation was therefore confined to inshore areas and to a lesser extent offshore. Clams found offshore were very large and white, while inshore they were moderately large and black in colour. On the average, clams were larger here than on the Bass River flats. No clams were found in areas of rippled sand, which occurred inshore.

There were two sites chosen for aging samples. Site 6 (area A, inshore) was very wet and muddy on the surface. Underneath there was some sand overlaying hard clay. Clams were moderately dense in number and medium to large in size; there were few small clams. Offshore site 7 (area D), located among numerous tidal channels, was very sandy. Clams exhibited a wide size range and were of a moderate density.

3.1.3 Five Islands Flats

3.1.3.1 Harrington Beach

Harrington Beach, located at the mouth of the Harrington River, was the only Five Islands flat surveyed (Figure 7). Like Carrs Brook, it has historically been a good producer and is still heavily exploited today due to its proximity to Five Islands, where the majority of commercial clam diggers live. The portion of this flat inside the Harrington River Channel up to high water mark is closed to digging all year, due to bacterial pollution; therefore it was not surveyed. From the channel seaward, the flat was 436 m wide. Inshore sediments imported from the adjacent salt marsh were a black mud-sand-clay mixture; this eventually graduated into lighter coloured mud-sands offshore. To the west, sandstone ledges became more common, while easterly there was a predominance of gravel in the sediments. Few clams were found in the latter two offshore substrate types.

Juveniles from the previous year's settlement were observed inshore, but in lower densities than on Sadies.

Offshore aging site 8 was chosen in a commercially worked area. Digging here was difficult because of the concentration of gravel and rock. Clams were moderately dense but patchy. Some animals appeared small and stunted, while others were larger and seemed to have normal growth rates. This phenomenon probably was related to substrate type as the large animals were concentrated in sandier spots.

The area in which inshore site 9 was located, near the main Harrington River channel, had been recently dug by fishermen. A moderately dense group of clams with a wide size distribution were found in the sample in a substrate of black mud over a sand-gravel bottom. Thick shelled, stunted clams, and clams with shock marks, were observed at this site.

3.1.3.2 Moose Island

A largely sandy clam flat, Moose Island was not surveyed in detail. It was visited at the beginning of August to determine its approximate acreage, to estimate the densities and sizes of clams, and to collect an aging sample. Recent commercial digging was apparent at that time. Small and medium size clams were found in moderate abundances interspersed with large numbers of dead shells. Clams were thin shelled, did not seem to be stunted, and showed some variability of growth rates. There were juveniles present, but densities were lower than at Sadies. Midshore aging site 10 (Figure 7) was representative of these general characteristics.

3.1.4 Advocate Harbour

Advocate Harbour (Figure 8) was visited at the end of August, but was not surveyed. The trip from Lower Economy took approximately 1 1/2 hours. Over the last two years, fishermen from the Five Islands area have been travelling to Advocate Harbour to dig clams. This adds considerable time and expense to their fishing efforts, and therefore is not a regular occurrence.

There are two areas of commercially exploitable clams in the harbour. Access to one, Lubber Hole, is limited by distance and transportation problems; therefore it is probably less exploited. The second and major digging area is approached from the main town road. The flat stretches from Bog Brook around to Burke Brook, and then seaward toward aging sample site 14. A much larger area than was originally thought, it is likely also underexploited. The area consists mainly of very deep sand, with muddy sections at the mouths of brooks. The harbour is dissected by many channels. Clams at the aging site were mostly large (>50 mm), white in colour, and thin shelled, and their distribution was moderately dense. Nearby, evidence of digging activities were in abundance.

3.1.5 Remaining Unsurveyed Flats

Unsurveyed flats received cursory inspections. Information on flat dimensions, and on densities and sizes of clams, was recorded. Some flats, such as Eddy's Beach and Sand Point (Figure 7), both in the Five Islands area, which had been historically good producers, were heavily dug over four years ago; however, they became important again in 1982. A strong year class of 1 3/4" - 2" (42-54 mm) clams attracted many clam diggers, and harvesting became rather intense during the latter part of the summer. Nearby Broderick's Beach, a very large flat, has also contributed significantly to the fishery in the past. Although difficult to work because it is very muddy, it will likely continue to be important in the future because of its size and proximity to Five Islands.

The Soleytown area at Lower Economy (Figure 6), also traditionally a good digging area, did not seem very productive in 1982, nor did it appear to have any significant future potential.

The rest of the flats were either very small, low in productivity, or difficult to access because of position or distance, and therefore will only be marginal contributors to the commercial fishery in the future.

3.2 The Fishery

The commercial clam fishery is particularly important to the local economy of the study area. Digging occurs from about mid-May to mid-October. The traditional harvesting implement is the clam hack (rake) and the harvest unit is the bushel (four 2-gallon buckets). Prior to 1982, clams were hauled into shore in bushel size onion bags (potato bags earlier), and delivered to the clam buyers. Now, five gallon white plastic buckets have been recommended by Fisheries and Oceans Canada officials for sanitary purposes. A digger will usually use a wheeled cart, called a "gig", to haul in his catch. On very firm flats, access-

ible by road, motorized vehicles such as trucks and buggies are employed. The use of boats is minimal, except when the catch is large, or when the flat is isolated, such as Moose Island. Overall, the industry is largely unmechanized and requires low capital investment since most of the digging and processing is done by hand.

The recreational fishery here is considered to be more valuable than that on the Eastern Shore. Flats in the Minas Basin are large and numerous, easily accessible by car and on foot, and located near parks, camp grounds, cottages, and other tourist facilities. In the Five Islands area, flats utilized frequently by visitors in 1982 included The Park, Sand Point, and Harrington Beach. Carrs Brook and Soleytown (Lower Economy) were popular in the Economy area.

Besides visitors from other parts of Canada and from the United States, the area is heavily used by Nova Scotia residents, particularly from the Springhill and Truro areas. Fifteen percent of those interviewed during the survey were recreational fishermen.

3.3 Stock Assessment

Sampling information for the three locations studied along the north shore of the Minas Basin is summarized in Table 5. A total of 353.74 acres were covered by the survey. The greatest amount of acres surveyed, stations dug, and clams measured were on the Bass River flats. A further breakdown of this information on a per-area basis is found in Tables A3.1 - A3.3 in Appendix 3. Average number per ft^2 (0.09 m^2) and percentage size frequency distribution for all locations combined are presented in Table 6. (More detailed results by area and location are found in Tables A3.4 - A3.9). For the whole north shore, the highest density ($1.86/ft^2$) and percentage (25%) of clams were found in the 1 1/2" (36-41 mm) size class (Table 5, Figure 10). Forty-four percent of the population was concentrated between 1 1/2 - 1 3/4" (36-48 mm size class).

Table 5. Acreage surveyed, number of areas, number of stations, and number of clams measured for the three locations along the north shore of the Minas Basin.

Location	Acreage*	Number of areas	Number of stations	Number of clams
Bass River Flats	199.58	5	598	4,871
Economy Flats	116.87	5	315	2,067
Five Islands Flats	37.29	1	120	2,727
Total	353.74	11	1033	9,665

* 1 acre = 43,560 $ft.^2$ = .41 hectare
1 m^2 = 10.76 $ft.^2$

Table 6. Average number/ft^2 (.09 m^2) and percentage size frequency distribution of clams sampled on the north shore of the Minas Basin for all locations combined.

Size Class (inches)	(mm)	Average number/ft^2	Percentage of total number (%)
<3/4	0-16	0.44	6
3/4	17-22	0.33	5
1	23-29	0.89	12
1 1/4	30-35	1.57	21
1 1/2	36-41	1.86	25
1 3/4	42-48	1.39	19
2	49-54	0.51	7
2 1/4	55-60	0.22	3
2 1/2	61-67	0.10	1
2 3/4	68-73	0.03	<1
≥ 3	≥74	0.02	<1
Total		7.56	100

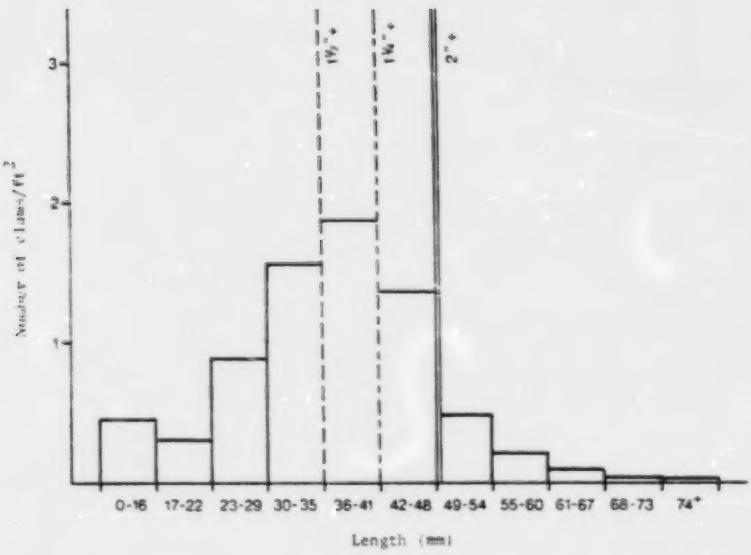

Figure 10. Size frequency distribution of the surveyed soft-shell clam population along the north shore of the Minas Basin, 1982.

Table 7. Summary of number/ft^2 (.09m^2) and percentage size frequency distribution for the three locations and all locations combined along the north shore of the Minas Basin.

Group	Bass River Flats Number/ft^2	%	Economy Flats Number/ft^2	%	Five Islands Flats Number/ft^2	%	All Locations Number/ft^2	%
Juveniles <3/4-1 1/4"	3.54	43	2.42	37	3.77	68	3.23	44
Prerecruits 1 1/2-1 3/4"	3.86	47	2.84	43	1.25	23	3.25	44
Markets ≥2"	0.75	9	1.29	20	0.49	9	0.88	12
Prerecruits 1 1/2"	2.33	29	1.44	22	0.61	11	1.66	25
Markets ≥1 3/4"	2.29	28	2.69	41	1.13	21	2.27	31
Total	8.15	100	6.55	100	5.51	100	7.36	100

Total average density for all size classes of 7.36 clams/ft^2 was recorded (Table 6). This figure is less than densities observed in a similar survey conducted on the Eastern Shore in 1981, where 26.71 and 13.10 clams/ft^2 were documented for Chezzetcook and Sonora harbours, respectively (Witherspoon, 1982).

Bimodality of the size frequency distribution, as depicted in Figure 10, is the result of a low number of 3/4" (17-22 size class) clams. The number per square foot of <3/4" (0-16 mm size class) animals is likely underestimated due to sampling procedures; therefore, this bimodality may have been stronger. A corresponding observation was made by Yeo (1978) for size frequencies of clams sampled along the south shore of the Minas Basin. There are a number of possible explanations for these findings. Success of spawning and settlement of young clams are known to vary from one year to the next (Brousseau, 1978). Therefore, densities of clams in the <3/4" (0-16 mm) size class and subsequent ones may fluctuate depending on the quantities of young produced at fertilization. Imposed on this natural fluctuation are environmental changes, which act on the intertidal zone once the clams have established themselves in the surface sediments. Increased erosion or accretion of sediments, bringing about removal or smothering, can be lethal to juvenile clams. Additional mortalities may be caused by animal predators and indirectly as a result of commercial digging.

A dominant modal group of 10 mm animals observed by Yeo (1978) in 1975-76 could explain the strong year class observed at the 1 1/2" (36-41 mm) size class in our size frequency distribution for 1982 (Figure 10). This, and the previous explanations, may partially account for this phenomenon, but it is more likely related to the accumulation in this size class of slow growing or stunted animals, which are found commonly on commercial flats along the north shore of the Minas Basin.

Such regular bimodality is not observed in other areas surveyed in the Maritimes (Robert, 1979; Robert and Smith, 1980; Robert, 1981; Witherspoon, 1982). Instead, single modal groups occur at a wide range of size classes, which suggest the possibility that specific and more severe environmental conditions may be acting to concentrate animals in juveniles and older size groups in the Minas Basin.

Comparisons of differences in densities between the three locations and between size groups were made (Table 7, Figure 11). The highest total number of 8.15 clams/ft^2 was observed on the Bass River flats, followed by Economy and Five Islands at 6.55 and 5.51 clams/ft^2, respectively.

Juvenile d[illegible]ies were found to be similar for all locations, with the Economy flats being slightly lower than the others. The combined juvenile density of 3.23 clams/ft^2 is considered relatively low, compared to other locations surveyed in the Maritimes. For the Chezzetcook and Sonora areas on the Eastern Shore of Nova Scotia, juvenile densities were 19.75 and 6.97 clams/ft^2, respectively (Witherspoon, 1982). In New Brunswick at Eel River Cove, 19.9 juveniles/ft^2 were recorded in 1978 (Robert, 1979).

Overall, prerecruit (1 1/2 - 1 3/4" size classes, 36 - 48 mm) densities of 3.25 clams/ft^2 are comparable to values of 4.80 and 3.53 for Chezzetcook and Sonora Harbors, respectively. Market size clams ($\geq$ 2" size class, $\geq$49 - 54mm) in the Minas Basin were approximately 60 - 70% less abundant than those of the Eastern Shore: density of 0.88 markets/ft^2 in the Minas Basin, compared to 2.16 and 2.58 for Chezzetcook and Sonora, is viewed as very low. An unfished population of clams at Eel River Cove, New Brunswick had market size clams with an average density of 20.2/ft^2.

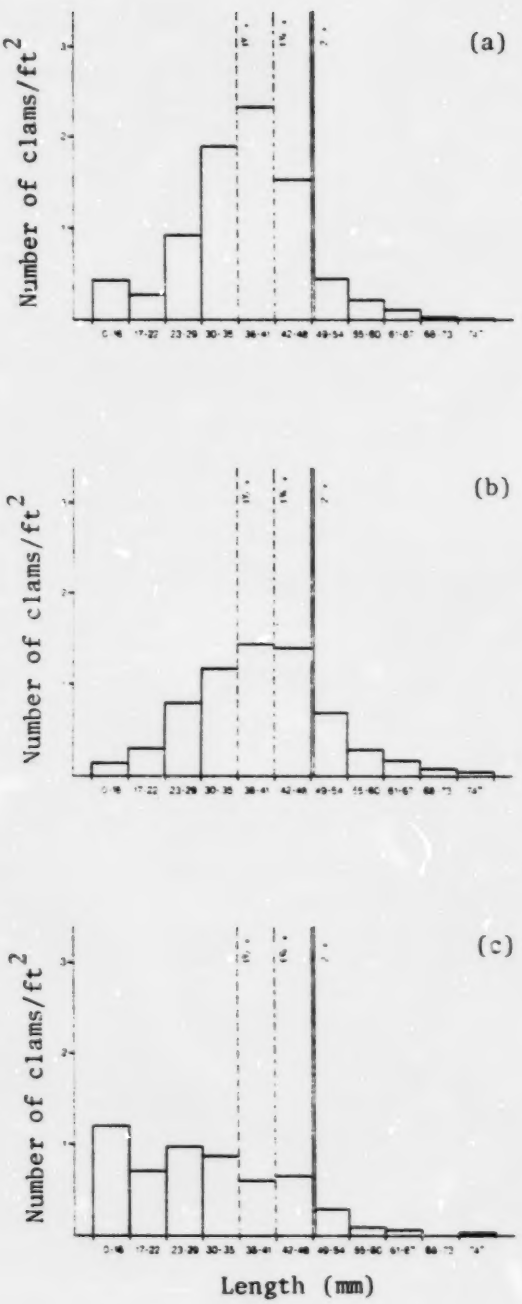

Figure 11. Size frequency distributions for all clams measured on (a) Bass River, (b) Economy, and (c) Five Islands flats.

Bass River flats had the highest densities of prerecruits for both Types 1 and 2. Markets were most abundant for both classification types on the Economy flats. Five Islands had lowest densities of prerecruits and markets of both types, but the most favourable number of juveniles at 3.77 clams/ft^2. Harrington Beach, the only flat surveyed at Five Islands, is an example of the result of overfishing. Harvests are likely to be poor here for 6 or 7 years until new recruits become available to diggers. The other locations have more promising numbers of prerecruits, which will slowly become available to the commercial fishery. This is true more so of the Bass River flats, where densities are largely a reflection of the accumulation of animals in prerecruit size classes, than the Economy flats.

A closer inspection of the distribution of clams on a per area basis can be observed in Tables A3.7 - A3.9. At 10.19 clams/ft^2, Sadies B had the greatest density of clams overall. The most abundant number of juveniles (5.13/ft^2) was found on Sadies C. Sadies B had the highest densities of prerecruits at 5.43/ft^2 and 3.38/ft^2 (Types 1 and 2, respectively). Market size clams were most highly concentrated in Carrs Brook C (1.54/ft^2, Type 1) and at The Tower (3.26/ft^2, Type 2).

Bushel per acre production (Table 8) is the calculation of total quantities of prerecruits and market size clams, and is useful for comparing areas of commercially harvested stocks. For all locations combined, production of $\geq$1 1/2" size classes ($\geq$36-41 mm) is moderately good at 86.62 bu/acre. Overall, prerecruits are more abundant than markets for Type 1, with the reverse being true for Type 2. Bushel per acre quantities of both prerecruit and market size clams for Bass River and Economy flats were 91.40 and 97.01, respectively. These quantities match other good to moderately abundant locations surveyed in New Bruns-

Table 8. Estimated bushels / acre of prerecruits and markets surveyed for individual locations and all locations combined on the north shore of the Minas Basin.

Group	Bass River Flats (bu/acre)	Economy Flats (bu/acre)	Five Island Flats (bu/acre)	All locations (bu/acre)
Prerecruits 1 1/2-1 3/4"	66.54	50.12	22.16	56.46
Markets ≥2"	24.86	46.89	16.94	30.16
Prerecruits 1 1/2"	36.25	22.40	9.49	28.94
Markets ≥ 1 3/4"	55.15	74.61	29.61	57.68
Total	91.40	97.01	39.10	86.62

Table 9. Estimated production (bushels)* of soft-shell clams in three locations surveyed along the north shore of the Minas Basin of the Bay of Fundy.

Group	Bass River Flats (bushels)	Economy Flats (bushels)	Five Islands Flats (bushels)	Total (bushels)
Prerecruits 1 1/2-1 3/4"	13,280.1	5,857.6	826.3	19,964.0
Markets ≥2"	4,961.5	5,480.0	631.7	11,073.2
Prerecruits 1 1/2"	7,234.8	2,617.9	353.9	10,206.6
Markets ≥ 1 3/4"	11,006.8	8,719.7	1,104.1	20,830.6
Total	18,241.6	11,337.6	1,458.0	31,037.2

*Production is based only on those flats which were surveyed by quadrat and transect line method.
One bushel = 60 lb. or 27 kg shell weight = $20 landed value in 1982.

Table 10. Estimated acreage and bushel production (≥ 1 3/4") of commercial clam producing locations not surveyed along the north shore of the Minas Basin of the Bay of Fundy in 1982.

Location	Acreage	Bushels
Bass River Flats	11.82	564.8
Economy Flats	208.16	9,625.6
Five Islands Flats	309.18	16,471.8
Advocate Harbour	233.04	19,621.1
Total	762.20	46,283.3

wick (Robert and Smith, 1980) and Prince Edward Island (Robert, 1981). In contrast, the Five Islands flat productivity at 39.10 bu/acre is low. High production figures of 157.6 bu/acre and 150.0 bu/acre were found for Chezzetcook Harbour and Sonora, respectively, in the 1981 survey along the Eastern Shore (Witherspoon, 1982). Bushel per acre production by individual flat is given in Appendix A3.10.

Total estimated numbers of bushels available on the surveyed flats are summarized in Table 9. The approximate acreages and numbers of bushels for the remaining non-surveyed commercial flats are given in Table 10 and A3.11. Along the entire north shore of the Basin, there was a combined potential of 1,115.94 acres of commercial clam flats with 67,113.9 bushels of market size clams ($\geq$1 3/4" size classes, $\geq$42-48mm) available for harvest at the time of the study (Table 11). If the entire resource were taken in 1982, it would have had a landed sale value of over 1.3 million dollars ($20/bushel). According to finalized statistics for 1982, 39% of this potential resource was landed (Table 12).

The 1982 survey was responsible for the in-depth study of only 32% of total commercial clam flats. The Five Islands flats have potentially the largest area of clam flats for exploitation, and Bass River the smallest.

3.4 Distribution

The survey was conducted to delineate densities of clams per height of the intertidal zone, but lack of time prevented the calculation of data. However, Little Bass River (Figure 5) and Carrs Brook (Figure 6) were broken up into areas which extended from inshore to offshore and can be studied as an alternative. Little Bass River B, an offshore area, had lower abundances of all size clams (Table A3.7). Generally, the same relationship existed in most flats studied.

Table 11. Estimated total acreage and potential bushel production (≥1 3/4") of soft-shell clams of both surveyed and non-surveyed areas along the north shore of the Minas Basin, Bay of Fundy, 1982.

Location	Acreage	Percentage (%) of location surveyed	Bushels
East of Economy Pt.			
Bass River Flats	211.40	94	11,571.6
West of Economy Pt.			
Economy Flats	325.03	36	18,345.3
Five Islands Flats	346.47	11	17,575.9
Advocate Harbour	233.04	0	10,621.1
Total	904.54	17	55,542.3
Overall Total	1,115.94	32	67,113.9

Table 12. Landings[a] (metric tons[b] shell weight) and value (dollars) of soft shell clams in statistical District 43, on the Five Islands-Economy shore of the Minas Basin, Bay of Fundy from 1943-1982.

Year	Landings	Total Value	Value per Bushel[c]
1982	710	527,000	20
1981	621	455,182	20
1980	560	369,441	18
1979	499	237,859	13
1978	608	309,162	14
1977	370	177,113	13
1976	332	132,562	11
1975	406	179,415	12
1974	531	204,168	10
1973	510	169,094	9
1972	281	80,519	8
1971	214	36,295	5
1970	109	20,594	5
1969	161	24,477	4
1968	170	25,429	4
1967	162	24,054	4
1966	156	17,208	3
1965	132	14,587	3
1964	161	17,778	3
1963	139	15,362	3
1962	193	21,306	3
1961	221	21,911	3
1960	195	19,047	3
1959	295	32,571	3
1958	258	28,400	3
1957	285	34,000	3
1956	251	29,500	3
1955	203	20,200	3
1954	166	14,600	2
1953	206	18,500	2
1952	372	28,600	2
1951-1947[d]			
1946	916	53,000	1
1945	343	12,478	1
1944	128	4,242	1
1943	54	1,629	1

[a] Taken from Table 3 of Fisheries and Oceans statistical records, and the Dominion Bureau of Statistics.

[b] One Metric ton = 1,000 kg = 2,205 lbs.

[c] One bushel = 60 lbs = 27 kg = 4 peck buckets = 8 gal (U.S. dry measures).

[d] No landing statistics available.

Yeo (1978), reporting densities of <1/ft^2 in the lower part of the intertidal zone on the south shore of the Minas Basin, supports these results.

The opposite trend at Carrs Brook was observed (Table A3.8). The inshore parts of the flat are easily accessed by diggers, whereas offshore areas are less available because of their great distance from shore and reduced digging times. As a result, areas A and B (Figure 6) have been heavily exploited while areas C and D have not.

Yeo (1978) explains reduced abundances of clams offshore as probably the result of "strong tidal currents and fluctuating sediment surface, which either cause erosional removal and/or poor spatfall patterns". Medcof (1945) proposed this view and further suggested that there may be increased predation by clam drills and flatfish in the lower part of the intertidal zone. Robert (1981) reports "silt and strong wave action limit clam distribution" offshore.

Lower survival of juveniles offshore is apparent at Little Bass River (Table A3.7); however, the opposite was true for Carrs Brook (Table A3.8). This seems to be a phenomenon related to the heavy fishing inshore on the Carrs Brook flat, producing greater mortalities of juveniles than exhibited offshore where fishing pressure is much less. In contrast, Little Bass River represents the average situation because fishing effort is more evenly distributed from inshore to offshore.

Another phenomenon generally noted during the survey and supported by data from Little Bass River (Table A3.7) and Carrs Brook (Table A3.8, Figure 12), was the increasing proportion of larger size clams seaward on intertidal clam flats. Lower densities of clams, greater distances, and shorter digging times make these areas less attractive to commercial diggers, resulting in lower harvesting pressure and larger clams.

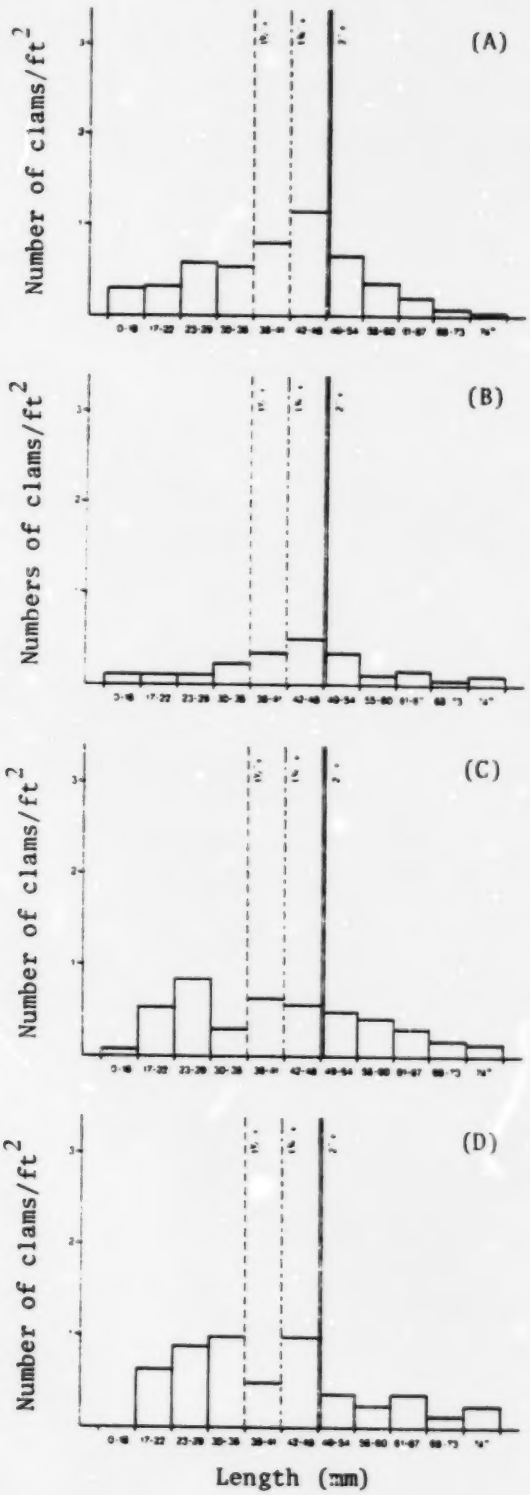

Figure 12. Size frequency distributions of clams, from inshore to offshore (areas A to D), for the Carrs Brook flat.

Reduced densities, stronger tidal currents, and longer submergence times also enhance growth as more food becomes available for this filter feeder bivalve.

3.5 Density

Clam distribution on intertidal flats was found to be contagious — patches of very high densities of clams were found adjacent to areas with little or no clams. Using a variance to mean ratio index, Yeo (1978) statistically provided that clams were aggregated. He explained this distribution by relating it to "the hydrodynamic sorting processes of larvae and juveniles in combination with better survival in locally sheltered areas", such as those described earlier under Section 3.1. Concentration of clams in the middle to upper parts of the intertidal zone is likely due to more suitable settlement conditions at the beginning of the ebb tide when tidal velocities are reduced. An additional explanation for this phenomenon was proposed by Dickie (1955) who postulated that clam larvae are "gregarious and settle thickest in areas occupied by their own species".

Substrate type also has a great deal to do with successful establishment of juveniles. Clam larvae settling out of the water column, require relatively large and stable particles for byssal attachment, after which they burrow into the substrate with their foot. Coarse grained sediments of Sadies C produced comparatively good sets of juvenile clams (Table A3.7). Long term survival is therefore dependent on the overall stability of the bottom sediments. Newcombe (1935) noted a scarcity of young set in soft muddy substrates or shifting ripple sands. As well, adult clams planted in the latter bottom type did not usually survive well because their siphons filled with sand causing smothering or reduced food intake.

Another adult requirement affecting densities is adequate space. Shallow substrate depths and heavily gravelled sediments such as those described in Section 3.1 reduce total volume available for growth.

Yeo (1978) summarized by saying "the major control over the establishment of Mya communities is dictated by an interaction between sediment stability and tidal currents". Further to this, long term survival of clams is enhanced in mixed substrate types and is likely a result of successful juvenile attachment, ease of burrowing to a moderate depth, space for growth, and bottom types not subject to large scale erosion or deposition for extended periods.

3.6 Growth

A market size regulation of 2" (51 mm) exists for most commercial clam areas of the Maritimes. In the Minas Basin, there are no length regulations and on average, it takes 8 years growth to reach a length of 2". In contrast, clams on the south shore of the Gulf of St. Lawrence have the highest growth rates in the Atlantic Provinces, producing 50 mm clams on the average after five or six years (Robert, 1979, 1981). On the Eastern Shore, growth seems to be more variable and depends on local environmental conditions — at Chezzetcook and Sonora, 8 years are needed to reach harvest size (Witherspoon, 1982), while Medcof (1946) reported that at Musquodoboit and Clam Harbours the age was lower. In Passamaquoddy Bay at the head of the Bay of Fundy, it takes five or six years for clams to reach legal size (Newcombe, 1935). Outside of the Maritimes, in northern Massachusetts, Brousseau (1979) established that only 2 years were required to reach a 50 mm size.

Early workers in the Minas Basin observed a wide range of ages at 50 mm. Medcof (1949) documented 5-6 years at Lower Economy and 8 years at Five Islands. Newcombe (1935) reported an age of 5 years for

Economy Point. This study also demonstrated the variability of ages (6 to 14 years) at 50 mm (Appendix 2). Not only were growth rates variable from place to place, but also from one year to the next. This phenomenon was apparent from aging the clams and was documented by Newcombe (1935).

Figure 13 and Table 3 show the divergent values for lengths at infinity (L_∞) and growth rates (k) calculated from the aging samples. The von Bertalanffy growth equation usually predicts that faster growing animals grow to a small size and slower growing animals grow to a large size. In the samples collected, both fast and moderately fast growing animals grew to small sizes. The moderately fast growing animals are indicative of the phenomenon of stunting, where an animal's growth is prematurely slowed down. Stunted clams usually are more rounded in shape, have thick shells, and do not grow much above a fixed size. In this study, clams in aging samples with L_∞ below 70 mm (2 3/4") were considered stunted, a characteristic demonstrated by half of the 14 samples collected. Growth to 50 mm, therefore, could take from 8 to 14 years for a large percentage of the Minas Basin clam population. Commercially, these animals are of concern because many of them could die of natural causes before reaching an acceptable size for harvesting. In fact, flats with high proportions of stunted clams were observed to have abundant numbers of dead clam shells, particularly Sadies. Medcof (1945) made similar mention about this matter during his early studies in the area.

The L_∞ parameter of the growth equation predicts that no animals will grow past 100 mm (4") in the Minas Basin. In fact, during the survey the largest live animal measured was 86 mm (3 1/3"). On the Eastern Shore (Witherspoon, 1982) and on the south shore of the Gulf of St. Lawrence

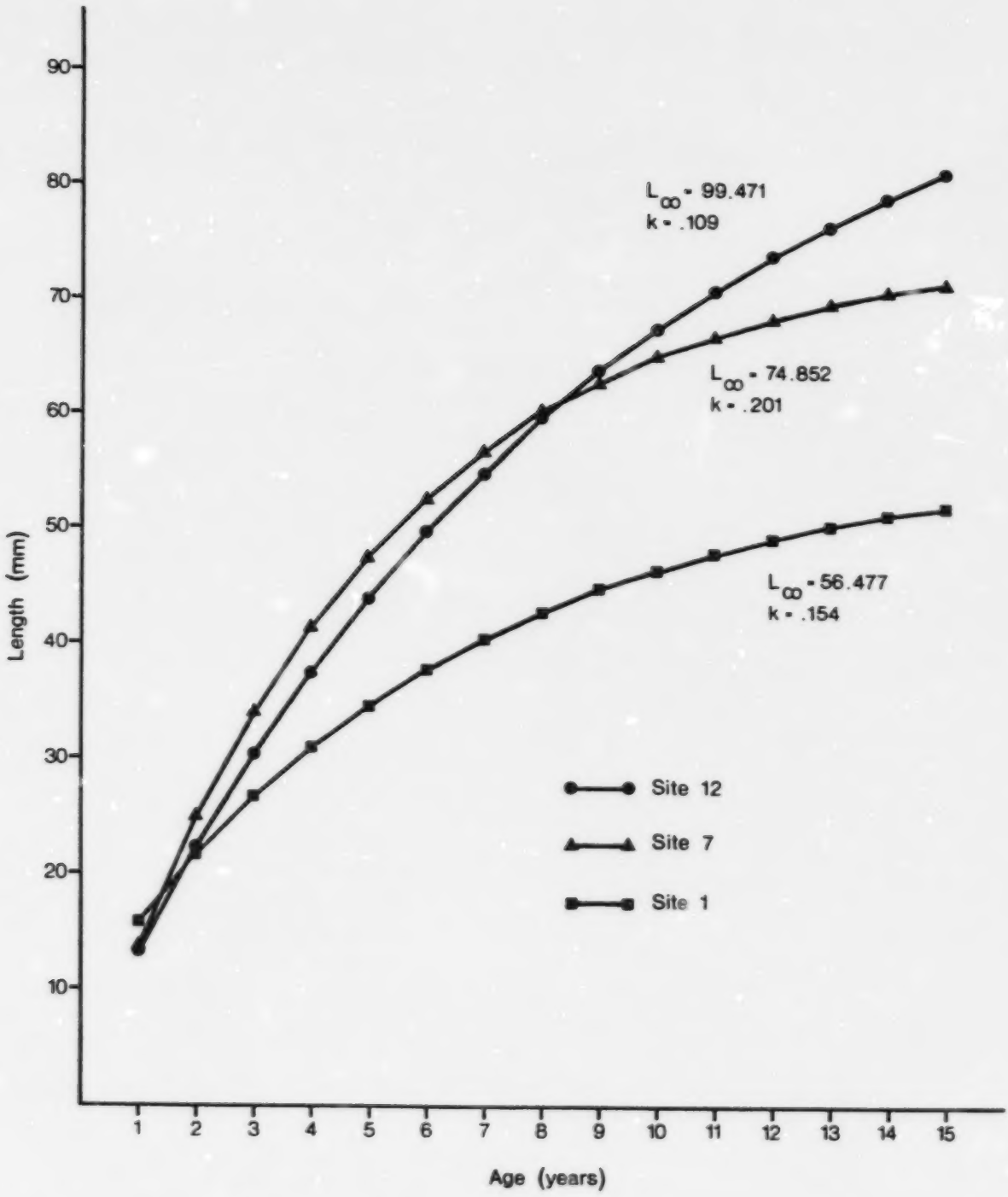

Figure 13. Length at age curves for slow (Site 12), medium-stunted (Site 1), and fast (Site 7) growing soft-shell clams on the north shore of the Minas Basin, 1982.

(Robert, 1979, 1981), some samples taken predicted growths above 100 mm (4").

Factors affecting growth rates and sizes of clams in the Minas Basin are both environmental and physical. Length of the growing season in the Bay of Fundy is short and extends from May to August inclusive (Newcombe, 1935). Growth during the first two months is greatest and is highly correlated with abundances of diatoms, the clam's most important food item. Newcombe reported that bottom diatoms, suspended into the water column from the intertidal zone, were the major type consumed. From September to December, growth is slowed down because of the reduced food supply. Low temperatures, January through to April, are postulated as being inhibitory growing conditions (ibid.). Yeo (1978) proposed that much of the food of benthic fauna in the Minas Basin was likely bottom diatoms and blue-green algae which bloom abundantly in the intertidal zone when the tide is out. He considered phytoplankton to be of minor importance as a food source for invertebrates because of its low relative density. Prouse (personal communication) reported that in the upper part of the Bay of Fundy, more particularly the Cumberland Basin adjacent to the Minas Basin, approximately one half of the organic carbon production is benthic diatoms, one quarter is phytoplankton, and the remainder is attributable mainly to salt marsh detrital production. Newcombe (1935) did not view detrital material as being an important food item for Mya.

Growth parameters k and L_∞ for all 14 aging samples were grouped by height in the intertidal zone. Clear cut trends were not apparent and no statistical analyses were carried out. Newcombe (ibid.) sampled inshore and offshore sites in one location and found growth rates offshore to be greater than those inshore. This tendency held true in some of our

locations but not in others (Table 3). One sample location, or even fourteen, may not be enough to draw any significant conclusions.

Stunted clams were mostly observed in the upper parts of the intertidal zones on those flats studied. Medcof (1945) stated that such clams normally live close to the surface in dense populations and at high beach levels. Yeo (1978) observed that when substrates were less than 8-10 cm deep over bedrock and clams were present, they showed indication of stunting of shell growth. Robert (1981) found stunted clams in Prince Edward Island associated with hard beach substrates (rocks, pebbles, gravel) and shallow, soft sediments. The phenomenon of stunting seems to be associated with crowding, and with shallow and/or gravelly beach substrates, usually occurring higher in the intertidal zone where space and food for growth are limited. Stunting is a major problem affecting the commercial industry in this region.

Strong tidal currents can increase growth rates by providing more food per unit of filtering time (Newcombe, 1935). Digging over flats several times during the period of a year resulted in 5-10% reduction of clam growth (Medcof, 1945).

In summary, the factors which control growth in clams include quantity and timing of diatom blooms, temperature, position in the intertidal zone, proximity to salt marsh estuaries, substrate type and depth, clam densities and digging frequency.

3.7 Reproduction

General gonad conditions were monitored from June through to September. Over the whole period no clear evidence of complete spawning was noted in the areas where the collections were made. Clams that were inspected appeared to be well developed by the end of June. Ripe gonads with distinct spawning veins were still apparent in the last week of July;

some spawning and spent clams were observed the final week of August. By the middle of September most clams observed had partially spawned and were beginning to develop new gonadal tissue.

In contrast, clams on the Eastern Shore were totally spent by August (Witherspoon, 1982). Battle (1933) studied clam condition near St. Andrews, N.B., at the head of the Bay of Fundy, during 1927-1928 and found a great number of mature specimens in June, with spawning reaching a peak about the middle of July. A secondary peak of mature individuals was observed in late July followed by a gradual shedding of germ cells until September. At this time, gonads were laden with immature germ cells. She linked the initiation of spawning with spring tides, occurring during the middle of the day when temperatures of the flats were relatively high. Medcof (1941) described the same phenomenon in Prince Edward Island. He also reported spawning in the Digby area during June and July (Medcof, 1945). Robert (1981) found peak spawning throughout July in Prince Edward Island.

Spawning in the Minas Basin is likely a gradual process initiated by warmed intertidal zones of midday tides. Assuming a 5 week larval period (Brousseau, 1978), settlement of juveniles would occur from September through to October.

3.8 Catch and Effort Data

Catch per unit effort figures calculated from fishermen interview data are summarized in Tables 13 and 14. An observed seasonal decline from May to August in CPUE is verified by fishermen's comments of fewer commercial size clams to be found in the fall. Commercial (76 interviewed) and recreational (13 interviewed) diggers had CPUE's of 2.36 and 0.80 buckets per hour, respectively. Total recreational effort is thought to be relatively low compared to commercial effort because there are

Table 13. Monthly commercial catch per unit effort* (C.P.U.E.) for clam diggers interviewed on the north shore of the Minas Basin in 1982. Recreational catch per unit effort is also noted.

Month	Catch (buckets)	Effort (hours)	CPUE	Number of diggers interviewed
May	86.00	35.00	2.46	10
June	324.00	133.50	2.43	39
July	8.00	5.00	1.60	2
Aug.	195.75	86.25	2.27	25
Total Commercial	613.75	259.75	2.36	76
Total Recreational	26.00	32.50	0.80	13

*Catch is measured in 2-gallon buckets, effort in hours dug.

Table 14. Catch per unit effort (C.P.U.E.) for commercial diggers in two areas along the north shore of the Minas Basin, 1982.

Area	Catch (buckets)	Effort (hours)	CPUE	Number of diggers interviewed
Sadies	343.00	145.00	2.37	43
The Tower	189.25	83.75	2.26	24

Table 15. Soft-shell clam landings (metric tons shell weight) and value (dollars) for District 43 as compared to the totals for Nova Scotia 1980-82.

	District 43			Nova Scotia			% Nova Scotia	
Year	Landings	Value	Value/ Bushel	Landings	Value	Value/ Bushel	Landings	Value
1982	710	527,000	20	2,379	1,639,000	19	30	32
1981	621	455,182	20	2,136	1,504,014	19	29	30
1980	560	369,441	18	2,143	1,420,353	18	26	26

fewer numbers of fishermen, less hours dug, and lower CPUE's. Catch per unit effort statistics for Sadies and The Tower (Table 14) did not appear to differ significantly.

3.9 Landing Statistics

District 43 landings since 1943 are summarized in Table 12. Soft-shell clam landings are given in metric tons (MT) shell weight and include unspecified clams which are considered to be Mya. Value in dollars per bushel is rounded to the nearest dollar. Landing data is not available for the years 1947 to 1951. Figures for 1982 are complete, as of March 1983. Clams dug in Advocate Harbour, District 44, are reported in District 43. In the last three years, approximately 3% of the total landings reported from this area were shipped from Petpeswick Harbour on the Eastern Shore.

Overall, landing values are said to be underestimated because of the quantities of clams sold privately and dug by tourists. One fishery officer suggested a figure of 10% as that which might not be reported. It seems statistics records on this shore are better than in past years, and more accurate than landing statistics for the Eastern Shore (Witherspoon, 1982).

Early in the fishery, landings reflected abundance of marketable clams (Figure 2). More recently they reflect the increased product demand and therefore price per bushel. Landings to date (1982) are the highest since the early 1940's and are a result of greater fishing effort (larger numbers of fishermen) rather than improved CPUE figures, which have been declining since the 1940's. Additionally, greater harvests of small steamer clams (1 1/2 - 1 3/4" size classes, 36-48 mm) in the last 3 years have been increasing to offset lower catch success and to meet U.S. market demands. In previous years, the catches were concentrated around 2" (51 mm). The popularity, and therefore harvest, of steamer clams is

likely to continue.

The value of this fishery in relation to the total Nova Scotian clam fishery has increased since the 1970's (Figure 1). In the last few years it has been worth approximately 30% (Table 15). In 1981 the clam landings in District 43 represented 90% of the landed weight of all fish species in that District, and 67% of the value.

4. Discussion

The landed value of the Minas Basin clam fishery is substantial in comparison to that of the total provincial clam fishery and has become more valuable in recent years. Present economic conditions and lack of management regulations may impact on the long-term stability of the fishery.

Size regulation prompted by complaints about harvesting of small clams has become an important issue in the last few years. Absence of size limit legislation has allowed a trend to fishing smaller and smaller clams. There is also some evidence of lowered stock abundances as compared to earlier years of the fishery.

Compared to other Maritime clam stocks, present densities of clams indicate the industry is relatively healthy. However, a number of factors may impact on the fishery in the future to reduce abundances significantly. Growth rates of clams are low and stunting is found in a high proportion of the population which causes animals to accumulate in 1 1/2 - 1 3/4" size classes (36-48 mm). Increased fishing pressures will likely raise the proportion of clams harvested between these sizes. Bacterial problems may cause processors to do away with local shucking practices which will further encourage the harvest of small clams. The major concern with depletion of stocks in this size range is related to the

length at maturity. Brousseau (1978) stated that clams are sexually mature at 1 1/2" (40 mm). Reproductive success and ultimately future stock abundance could be lowered by such practices. Establishment of juveniles in the Minas Basin is already known to be subject to great natural hazards.

Increased bacterial pollution and the potential development of a tidal power barrage may also threaten the economic viability of the fishery (Witherspoon, submitted for publication).

4.1 Management Recommendations

The Minas Basin clam flats are extensive and many places are unsuitable for commercial digging. Although likelihood of extinction of this species by overfishing is remote, numbers could be reduced to levels which would not provide for economic harvesting.

To ensure the economic future of this fishery, the following recommendations are made:

1) A relatively high proportion of clams that are found on commercial flats are stunted and may never reach 2" (51 mm) market size. Many of the other clams are slow growing and reach the same size after 6-9 years, thereafter increasing in length with relatively small yearly increments. Clams reproduce for the first time at approximately 1 1/2" (40 mm). At present, diggers harvest at 1 3/4" (45 mm). A size limit of 2" would mean that there would not be a commercial fishery and one of 1 1/2" (40 mm) would eliminate a fishery for the future. An optimal choice economically and biologically would be to harvest at a mean size of 1 3/4" (45 mm), which would allow animals one or two years of reproduction before being harvested. Stringent enforcement of this size limit would be necessary since the difference between 40 and 45 mm is very small.

2) Dickie and Medcof (1955, 1956) have discussed the inefficiency of harvesting practices which result in high mortality rates in clams. They found that on a flat dug over once, only 60% of marketable clams are removed by diggers, and that 50% of the remaining clams die because of smothering, exposure, body damage, or gull predation; further, the more often a flat is dug over, the greater are the mortalities. They suggested if flats were cropped once per year that the "eventual increase in CPUE would be enough to offset or even over-compensate for the loss of catch from the reduction in the total amount of digging". Other advantages of a larger standing stock besides increased yield and reduced labour were summarized, and these included: a larger spawning stock; promotion of better settlement of larvae because of their gregarious nature; increase in growth rates due to lowered disturbances; and, maintenance of suitable physical conditions for settlement due to exclusion of competitors. Therefore, controls on the digging frequencies of flats would eventually lead to increases in yield.

3) Improvements in handling practices could also increase yield through reducing the amount of wastage. Clams are often broken during digging or in transportation to the processing plants and are usually thrown away. A reduction in the proportion of broken clams could eventually bring greater returns to the fishermen.

4) During July and August of 1982, commercial harvest on some flats ceased because of high bacterial counts in clams. Unless proper point and non-point pollution control methods are employed to treat waste produced along the Minas Basin shoreline, pollution will continue to be an increasing problem for the commercial fishery.

5) The recreational clam fishery is not a major threat to the commercial fishery in the area. However, the recreational digger has a habit of walking all over a flat and using shovels to take clams, causing smothering and excessive shell breakage. Locating dense groups of large clams determines the commercial fisherman's ability to make a living. Many of these fishermen are in favour of licensing and limiting recreational diggers to flats that are not particularly important to the fishery. The fees could then be applied to enforcing these regulations.

Cooperation between commerical, recreational, and governmental individuals is a necessary prerequisite for effective management of the Minas Basin clam fishery.

5. Summary

1) Three hundred and fifty-four acres, or one-third of the total commercially harvestable flats (1,116 acres), were surveyed during the summer of 1982.

2) Standing stocks ($\geq$1 3/4" size classes, $\geq$42-48 mm) of 67,114 bushels, worth over 1.3 million dollars in 1982, were determined as being available to the commercial fishery.

3) Landings computed for 1982, using finalized data as of March 1983, indicate that only 39% of this potential has been harvested.

4) The greatest concentrations of clams occur between 36-41 mm (1 1/2" size class).

5) In recent years there has been low juvenile production which may affect future harvest, particularly if the trend for taking proportionally more steamer size clams continues. Generally, the present stock status appears to be healthy.

6) Growth rates are low and stunting common along this shore.

7) Recreational effort is not considered a threat to the commercial fishery.

8) A size limit of 45 mm or 1 3/4" is recommended on both biological and economical grounds. Other management proposals are presented.

References

Battle, H.I. 1933. Rhythmic sexual maturity and spawning of certain bivalve molluscs. Contr. Can. Biol. and Fish. 7(20):255-276.

Brousseau, D.J. 1978. Spawning cycle, fecundity and recruitment in a population of Mya arenaria (soft-shell clam) from Cape Ann, Massachusetts. Fish. Bull. U.S. 76:155-166.

Brousseau, D.J. 1979. Analysis of growth rate in Mya arenaria using the von Bertalanffy equation. Mar. Biol. 51:221-227.

Dickie, L.M. 1955. Soft-shell clam investigations. In: The Annual Report of the Biological Station, St. Andrews, New Brunswick.

Dickie, L.M. and J.C. Medcof. 1955. Soft-shell clam investigations. In: The Annual Report of the Biological Station, St. Andrews, New Brunswick.

Dickie, L.M. and J.C. Medcof. 1956. Soft-shell clam investigations. In: The Annual Report of the Biological Station, St. Andrews, New Brunswick.

MacPhail, J.S. and J.C. Medcof. 1955. 1947 clam investigations. Fish. Res. Bd. Can. Atl. Biol. Sta. MS Rep. No. 855: 98 p.

Medcof, J.C. 1941. Soft-shell clam investigations. In: The Annual Report of the Biological Station, St. Andrews, New Brunswick.

Medcof, J.C. 1945. Soft-shell clam investigations. In: The Annual Report of the Biological Station, St. Andrews, New Brunswick.

Medcof, J.C. 1946. Soft-shell clam investigations. In: The Annual Report of the Biological Station, St. Andrews, New Brunswick.

Medcof, J.C. 1949. 1944 investigations oysters and clams. J. Fish. Res. Bd. Can. MS Rep. No. 378.

Newcombe, C.L. 1935. Growth of Mya arenaria L. in the Bay of Fundy Region. Can. J. Res. 13D(6):97-137.

Robert, G. 1979. Fourth survey of Eel River Cove, N.B. soft-shell clam (Mya arenaria) population. Fish. Mar. Serv. MS Rep. 1941: 14 p.

Robert, G. 1981. Stock assessment of soft-shell clams in open shellfish growing areas of Prince Edward Island. Can. MS Rep. Fish. Aquat. Sci. 1606: XIV + 47 p.

Robert G. and D.W. Smith. 1980. Surveys of soft-shell clam (Mya arenaria) populations in some closed areas of Charlotte County, New Brunswick. Can. MS Rep. Fish. Aquat. Sci. 1967: 59p.

The Women's Institute, Five Islands (ed.). 1969. The Story of Five Islands Colchester County, Nova Scotia. The Tribune Press Ltd., Sackville, New Brunswick.

Witherspoon, N.B. 1982. Population surveys of the soft-shell clam (Mya arenaria) in selected estuaries on the Eastern Shore of Nova Scotia, 1981. N.S. Dept. Fish. Man. & Tech. Rep. Ser. No. 82-03: 48 p.

Witherspoon, N.B. The soft-shell clam (Mya arenaria) resource along the north shore of the Minas Basin and potential impacts of the proposed tidal power project on its long-term productivity. Can. Tech. Rept. Fish. & Aquat. Sci. (submitted for publication).

Yeo, R.K. 1978. Animal-sediment interactions and the ecology of the intertidal mudflat environment, Minas Basin, Bay of Fundy, Nova Scotia. M.Sc. thesis, McMaster Univeristy, 396 p.

APPENDIX 1

Form used for interviewing commercial and recreational clam fishermen.

Clam Fisherman Interview Form

Date: _____ Clam Flat: _____

Interviewer: _____ Time: _____

Total number of fishermen on flat: _____

Fisherman type: Recreational _____ Commercial _____

Number of hours digging: _____ Number of buckets*/day: ___

Total number of hours expected to dig: _____

Over what months do you intend to dig?: _____

How many days per month do you dig on average?: _____

Clam size range: _____ Average clam size: _____

Commercial Fishermen:

Historical information on Fishery (i.e. best year yet, etc.):

Present status of Fishery:

Major concerns of Fishery management:

What do you know and think about Fundy Tidal Power?

Recreational Fishermen:

How long do you intend to be in the area?: _____

How many days do you expect to dig?: _____

How many people in your party will be digging?: _____

How important is clam digging in relation to your overall holiday plans?

low _____ medium _____ high _____

Will you return to the area for clam digging this year _____

or in the future?: _____

* 1 bushel = 4 peck buckets (1 peck = 2 gallon bucket)

APPENDIX 2

Length at age for soft-shell clams collected along the north shore of the Minas Basin, 1982.

Table A2.1. Length (mm) at age (years) for soft-shell clams collected at Site 1 - Sadies A - Midshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	187	15.8	6	15.8
2	176	21.6	5	21.7
3	168	26.6	4	26.6
4	143	30.8	4	31.0
5	107	34.5	3	34.5
6	69	37.6	3	37.5
7	17	40.3	2	39.9
8	2	42.6	2	44.0
9	1	44.6	2	52.0
10	-	46.3	2	-
11	-	47.8	1	-
12	-	49.0	1	-
13	-	50.1	1	-
14	-	51.0	1	-
15	-	51.8	-	-

Table A2.2. Length (mm) at age (years) for soft-shell clams collected at Site 2 - Sadies B - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	195	14.1	7	14.2
2	176	21.2	6	21.2
3	156	27.0	5	26.9
4	130	31.9	4	32.0
5	82	35.9	3	36.0
6	40	39.2	3	40.0
7	9	42.1	2	40.6
8	3	44.4	-	43.3

Table A2.3. Length (mm) at age (years) for soft-shell clams collected at Site 3 - Sadies C - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	201	12.8	7	13.0
2	190	20.0	6	19.6
3	180	26.2	5	26.2
4	171	31.5	5	31.8
5	152	36.0	4	36.4
6	110	39.9	3	39.9
7	51	43.2	3	43.0
8	18	46.1	2	45.6
9	7	48.5	2	48.7
10	3	50.6	-	50.3

Table A2.4. Length (mm) at age (years) for soft-shell clams collected at Site 4 - Sadies A - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	210	13.0	9	12.9
2	198	21.8	8	22.0
3	182	29.4	7	29.6
4	148	36.0	6	36.2
5	105	41.8	5	41.7
6	19	46.9	4	44.8
7	2	51.2	4	50.0
8	1	55.1	3	57.0
9	1	58.4	3	63.0
10	1	61.3	3	64.0
11	1	63.8	2	67.0
12	1	66.0	2	69.0
13	1	67.9	-	70.0

Table A2.5. Length (mm) at age (years) for soft-shell clams collected at Site 5 - Sadies A - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	204	12.4	7	12.5
2	195	19.3	6	19.0
3	176	25.2	5	25.2
4	120	30.1	4	30.1
5	61	34.3	4	34.8
6	20	37.8	3	37.4
7	8	40.7	3	39.5
8	1	43.2	-	42.0

Table A2.6. Length (mm) at age (years) for soft-shell clams collected at Site 6 - Carrs Brook - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	192	13.7	10	14.0
2	188	24.1	9	23.4
3	158	33.0	8	32.9
4	98	40.6	7	41.0
5	36	47.1	6	47.3
6	20	52.7	5	53.8
7	7	57.6	4	55.3
8	4	61.7	4	62.8
9	2	65.2	3	64.0
10	1	68.2	3	63.0
11	1	70.8	-	66.0

Table A2.7. Length (mm) at age (years) for soft-shell clams collected at Site 7 - Carrs Brook - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	209	13.6	11	13.9
2	144	24.8	9	24.2
3	99	33.9	7	33.7
4	62	41.3	6	41.8
5	34	47.4	5	48.4
6	25	52.4	4	53.0
7	12	56.5	3	57.5
8	4	59.9	3	61.0
9	3	62.6	2	60.3
10	1	64.8	2	54.0
11	1	66.6	2	57.0
12	-	68.1	1	-
13	-	69.4	1	-
14	-	70.4	1	-
15	-	71.2	-	-

Table A2.8. Length (mm) at age (years) for soft-shell clams collected at Site 8 - Harrington Beach - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	219	15.6	9	15.7
2	172	24.7	8	24.2
3	116	32.5	7	32.8
4	65	39.1	6	39.4
5	30	44.8	5	44.8
6	10	49.6	4	49.5
7	4	53.7	4	50.8
8	2	57.2	-	58.0

Table A2.9. Length (mm) at age (years) for soft-shell clams collected at Site 9 - Harrington Beach - Inshore

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	202	13.8	9	13.9
2	153	23.0	-	22.6
3	94	30.4	6	30.4
4	64	36.3	5	36.9
5	44	41.0	4	41.3
6	30	44.9	3	44.7
7	16	47.9	3	47.1
8	6	50.4	2	50.0
9	1	52.3	-	54.0

Table A2.10. Length (mm) at age (years) for soft-shell clams collected at Site 10 - Moose Island - Midshore

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	166	14.2	10	14.1
2	130	23.7	8	23.8
3	100	31.6	7	31.7
4	43	38.1	5	37.4
5	11	43.5	4	43.8
6	4	47.9	4	50.0
7	3	51.6	3	52.7
8	1	54.6	-	51.0

Table A2.11. Length (mm) at age (years) for soft-shell clams collected at Site 11 - The Tower - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	224	14.5	9	14.5
2	194	23.1	7	23.1
3	164	30.1	6	30.7
4	53	35.8	5	34.7
5	19	40.4	4	39.4
6	19	44.1	3	43.7
7	14	47.1	2	48.3
8	4	49.5	-	51.0

Table A2.12. Length (mm) at age (years) for soft-shell clams collected at Site 12 - The Tower - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	193	13.4	9	13.5
2	193	22.3	8	22.0
3	180	30.3	7	30.5
4	121	37.4	6	37.3
5	0	43.8	6	43.0
6	-	49.6	5	-
7	-	54.7	5	-
8	-	59.4	4	-
9	-	63.5	4	-
10	-	67.2	3	-
11	-	70.5	3	-
12	-	73.5	3	-
13	-	76.2	2	-
14	-	78.6	2	-
15	-	80.8	-	-

Table A2.13. Length (mm) at age (years) for soft-shell clams collected at Site 13 - Little Bass River - Midshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	276	10.3	7	10.5
2	275	17.6	-	17.2
3	265	24.3	6	24.2
4	198	30.4	6	30.6
5	100	35.9	5	36.2
6	28	40.9	5	40.1
7	7	45.4	4	44.4
8	3	49.5	-	46.3

Table A2.14. Length (mm) at age (years) for soft-shell clams collected at Site 14 - Advocate Harbour - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	229	12.9	8	13.1
2	226	20.9	-	20.7
3	193	27.9	6	27.8
4	153	34.0	6	34.2
5	107	39.3	5	39.8
6	67	44.2	4	44.7
7	36	48.5	4	48.4
8	11	52.2	3	52.5
9	2	55.4	3	53.0
10	1	58.3	-	49.0

APPENDIX 3

Details of acreage and sampling stations, frequency distributions, number/ft^2 by size class, and bushels/acre production figures for all clam-producing areas along the north shore of the Minas Basin, 1982.

Table A3.1 Size and number of sampling stations for the clam producing areas on the Bass River flats surveyed.

Area	Size ft²	Size m²	Size acres	Number of sampling stations
Sadies A	3,881,008	360,546	89.10	273
B	2,218,300	206,080	50.93	144
C	1,275,887	118,530	29.29	96
Subtotal Sadies	7,375,195	685,156	169.32	513
Little Bass River A	1,143,598	106,240	26.25	74
B	174,512	16,212	4.01	11
Subtotal Little Bass River	1,318,110	122,452	30.26	85
Total	8,693,305	807,608	199.58	598

Table A3.2 Size and number of sampling stations for the clam producing areas on the Economy flats surveyed.

Area	Size ft²	Size m²	Size acres	Number of sampling stations
Carrs Brook A	1,881,396	174,800	43.20	118
B	248,671	23,101	5.71	18
C	585,853	54,426	13.45	39
D	81,096	7,534	1.86	8
Subtotal Carrs Brook	2,797,216	259,861	64.22	183
The Tower	2,293,415	213,058	52.65	132
Total	5,090,631	472,919	116.87	315

Table A3.3 Size and number of sampling stations for the clam producing areas on the Five Islands flat.

Area	Size ft²	Size m²	Size acres	Number of sampling stations
Harrington Beach	1,624,313	150,899	37.29	120

Table A3.4 Size frequency distribution of the clams sampled by location along north shore of the Minas Basin.

Size Class (mm)	Size Class (inches)	Clams found in samples: Bass River Flats Number	%	Economy Flats Number	%	Five Islands Flats Number	%
0-16	<3/4	258	5	48	2	145	22
17-22	3/4	164	3	92	5	85	13
23-29	1	554	11	252	12	118	18
30-35	1 1/4	1143	23	371	18	104	16
36-41	1 1/2	1392	29	454	22	73	11
42-48	1 3/4	915	19	441	21	77	12
49-54	2	270	6	218	11	35	5
55-60	2 1/4	123	2	92	4	12	2
61-67	2 1/2	38	1	58	3	9	1
68-73	2 3/4	11	<1	25	1	0	0
≥74	≥3	3	<1	16	1	2	1
Total		4871	100	2067	100	660	100

Table A3.5 Summary of the size frequency distribution for the north shore of the Minas Basin.

Size Class (mm)	Size Class (inches)	Clams found in samples: Number	%
0-16	<3/4	451	6
17-22	3/4	341	5
23-29	1	924	12
30-35	1 1/4	1618	21
36-41	1 1/2	1919	25
42-48	1 3/4	1433	19
49-54	2	523	7
55-60	2 1/4	227	3
61-67	2 1/2	105	1
68-73	2 3/4	36	<1
≥74	≥3	21	<1
Total		7,398	100

Table A3.6 Number/ft^2 (.09m^2) in each size class for the three locations along the north shore of the Minas Basin.

Size Class (mm)	Size Class (inches)	Bass River Flats number/ft^2	Economy Flats number/ft^2	Five Islands Flats number/ft^2
0-16	<3/4	0.43	0.15	1.21
17-22	3/4	0.27	0.29	0.71
23-29	1	0.91	0.80	0.98
30-35	1 1/4	1.91	1.18	0.87
36-41	1 1/2	2.33	1.44	0.61
42-48	1 3/4	1.53	1.40	0.64
49-54	2	0.45	0.69	0.29
55-60	2 1/4	0.21	0.29	0.10
61-67	2 1/2	0.06	0.18	0.08
68-73	2 3/4	0.02	0.08	0
≥ 74	≥3	0.01	0.05	0.02
Total		8.15	6.55	5.51

Table A3.7 Number ft^2 (.09m^2) in each size class by area, for the Bass River flats.

Size Class (inches)	Size Class (mm)	Sadies A	Sadies B	Sadies C	Sadies Total	Little Bass River A	Little Bass River B	Little Bass River Total
<3/4	0-16	0.03	0.09	2.28	0.47	0.18	0.36	0.23
3/4	17-22	0.29	0.31	0.33	0.30	0.11	0	0.09
1	23-29	1.01	1.06	0.66	0.96	0.73	0.82	0.74
1 1/4	30-35	1.44	2.60	1.86	1.85	2.46	1.09	2.28
1 1/2	36-41	1.47	3.38	2.69	2.23	3.16	1.09	2.89
1 3/4	42-48	1.22	2.05	1.33	1.47	2.01	0.91	1.87
2	49-54	0.50	0.48	0.26	0.45	0.49	0.27	0.46
2 1/4	55-60	0.23	0.17	0.26	0.22	0.08	0.36	0.12
2 1/2	61-67	0.10	0.03	0.06	0.07	0.01	0.09	0.02
2 3/4	68-73	0.03	0.02	0	0.02	0	0	0
≥3	≥74	<0.01	0	0.02	0.01	0	0	0
Juveniles		2.77	4.06	5.13	3.58	3.48	2.27	3.34
<3/4 - 1 1/4"		43.8%	39.8%	52.6%	44.5%	37.7%	45.5%	38.4%
Prerecruits		2.69	5.43	4.02	3.70	5.17	2.00	4.76
1 1/2 - 1 3/4"		42.6%	53.3%	41.2%	45.9%	56.0%	40.1%	54.7%
Markets		0.86	0.70	0.60	0.77	0.58	0.72	0.60
≥2"		13.6%	6.9%	6.2%	9.6%	6.3%	14.4%	6.9%
Prerecruits		1.47	3.38	2.69	2.23	3.16	1.09	2.89
1 1/2"		23.3%	33.2%	27.6%	27.7%	34.2%	21.8%	33.2%
Markets		2.08	2.75	1.93	2.24	2.59	1.63	2.47
≥1 3/4"		32.9%	27.0%	19.8%	27.8%	28.1%	32.7%	28.4%
Total		6.32	10.19	9.75	8.05	9.23	4.99	8.70
		100%	100%	100%	100%	100%	100%	100%

Table A3.8 Number ft^2 ($.09m^2$) in each size class by area, for the Economy flats.

Size Class (inches)	(mm)	Carrs Brook A	B	C	D	Total	The Tower
<3/4	0-16	0.30	0.11	0.08	0	0.22	0.06
3/4	17-22	0.32	0.11	0.54	0.63	0.36	0.20
1	23-29	0.58	0.11	0.85	0.88	0.61	1.07
1 1/4	30-35	0.55	0.22	0.31	1.00	0.49	2.14
1 1/2	36-41	0.81	0.33	0.62	0.50	0.66	2.53
1 3/4	42-48	1.16	0.50	0.56	1.00	0.96	2.01
2	49-54	0.67	0.33	0.49	0.38	0.59	0.84
2 1/4	55-60	0.36	0.11	0.41	0.25	0.34	0.22
2 1/2	61-67	0.20	0.17	0.31	0.38	0.23	0.12
2 3/4	68-73	0.08	0.06	0.18	0.13	0.10	0.05
≥3	≥74	0.03	0.11	0.15	0.25	0.08	0.02
Juveniles		1.75	0.55	1.78	2.51	1.68	3.47
<3/4 - 1 1/4"		34.6%	25.5%	39.6%	46.5%	36.2%	37.5%
Prerecruits		1.97	0.85	1.18	1.50	1.62	4.54
1 1/2 - 1 3/4"		38.9%	38.4%	26.2%	27.8%	34.9%	49.0%
Markets		1.34	0.78	1.54	1.39	1.34	1.25
≥2"		26.5%	36.1%	34.2%	25.7%	28.9%	13.5%
Prerecruits		0.81	0.33	0.62	0.50	0.66	2.53
1 1/2"		16.0%	15.3%	13.8%	9.2%	14.2%	27.3%
Markets		2.50	1.28	2.10	2.39	2.50	3.26
≥1 3/4"		49.4%	59.2%	46.7%	44.3%	19.6%	35.2%
Total		5.06	2.16	4.50	5.40	4.64	9.26
		100%	100%	100%	100%	100%	100%

Table A3.9 Number/ft^2 ($.09m^2$) in each size class for the Five Islands flat.

Size Class (inches)	(mm)	Harrington Beach
<3/4	0-16	1.21
3/4	17-22	0.71
1	23-29	0.98
1 1/4	30-35	0.87
1 1/2	36-41	0.61
1 3/4	42-48	0.64
2	49-54	0.29
2 1/4	55-60	0.10
2 1/2	61-67	0.08
2 3/4	68-73	0
≥3	≥74	0.02
Juveniles		3.77
<3/4 - 1 1/4"		68.4%
Prerecruits		1.25
1 1/2 - 1 3/4"		22.7%
Markets		0.49
≥2"		8.9
Prerecruits		0.61
1 1/2"		11.1%
Markets		1.13
≥1 3/4"4		20.5%
Total		5.51
		100%

Table A3.10 Estimated bushels/acre of prerecruits and markets for areas within locations on the north shore of the Minas Basin.

Locations and areas	Bushels/acre				
	Prerecruits 1 1/2-1 3/4"	Markets ≥2"	Prerecruits 1 1/2"	Markets ≥1 3/4"	Total
Bass River Flats					
Sadies A	47.03	28.70	22.87	52.86	75.73
B	93.17	22.01	52.58	62.60	115.18
C	68.18	18.56	41.85	44.89	86.74
Total Sadies	63.80	25.70	34.69	54.81	89.50
Little Bass River A	88.96	16.76	49.16	56.56	105.72
B	34.98	24.90	16.96	42.92	59.88
Total Little Bass River	81.99	17.90	44.96	54.93	99.89
Total Bass River Flats	66.54	24.86	36.25	55.15	91.40
Economy Flats					
Carrs Brook A	35.60	48.31	12.60	71.31	83.91
B	15.03	33.38	5.13	43.28	48.41
C	20.74	66.03	9.65	77.12	86.77
D	27.58	65.12	7.78	84.92	92.70
Total Carrs Brook	29.28	51.94	10.27	70.95	81.22
The Tower	79.16	41.34	39.36	81.14	120.50
Total Economy Flats	50.12	46.87	22.40	74.61	97.01
Five Islands Flat					
Harrington Beach	22.16	16.94	9.49	29.61	39.10
Total Five Islands Flat	22.16	16.94	9.49	29.61	39.10
Survey Total	56.46	30.16	28.94	57.68	86.62

Table A3.11 Estimated acreage, bushels/acre (≥1 3/4"), and bushel production of commercial clam producing flats not surveyed along the north shore of the Minas Basin, 1982.*

Locations and areas	Acreage	Bushels/ acre	Bushels
Bass River Flats			
Five Houses	7.04	42.92	302.2
Saints Rest	4.78	54.93	262.6
Total Bass River Flats	11.82		564.8
Economy Flats			
The Miller Place	18.09	81.14	1,467.8
Soleytown - Lower Economy	190.07	42.92	8,157.8
Total Economy Flats	208.16		9,625.6
Five Islands Flats			
Old Wife	8.25	42.92	354.1
Sand Point	55.29	81.14	2,865.4
Eddys Beach	51.06	81.14	4,145.2
Brodericks Beach	139.53	42.92	5,988.6
Moose Island	39.32	29.61	1,164.5
Blue Sac Beach	35.73	54.81	1,958.4
Total Five Islands Flats	309.18		16,471.8
Advocate Harbour Flats			
Lubbers Hole Flat	21.62	77.12	1,667.3
Advocate Flat	211.42	84.92	17,953.8
Total Advocate Harbour	233.04		19,621.1
Total Non-Surveyed Areas	762.20		46,283.3

*See Section 2.2.2.1 for estimation procedures.